REPORT

ON PROPOSED

SAGARMATI WATER SUPPLY

FOR

AJMER.

AJMER:
SCOTTISH MISSION INDUSTRIES COMPANY, LIMITED.

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REFERENCES.

No. 420, dated 2nd March 1909, from the Secretary, P. W. Department, Rajputana, to the Secretary to the Government of India in the P. W. Department.

Submits the Sagarmati Water Works Scheme for Ajmer, with proposals for a free grant and a loan to the Ajmer Municipality.

No. 84 C, dated 11th December 1909, from the Secretary to the Government of India in the Foreign Department, to the Chief Commissioner, Ajmer-Merwara.

Calls for a complete estimate of the project in the form in which it is finally accepted, and a clear statement of the Municipality's financial position.

LIST OF PLANS.

Reference number on Plan.	
A.	Index Plan or Topographical Survey Sheet.
1 & 1 *a-x*	General Plan and Longitudinal Section.
2.	Site Plan.
3.	Plan for Wells with details.
4.	Plan for the Establishment Quarters.
5.	Detailed Plan for the Circular Reservoir.
6	Section of Sagarmati Valley.
7.	Water Level in Observation Well, 1908.
8.	Survey of Sagarmati Valley.

Proposed Sagarmati Water Supply for Ajmer.

REPORT.

Amounting to Rs 4,83,461 without Establishment and Tools and Plant charges, Rs. 5,19,462 with Establishment and Tools and Plant charges.

1. In 1908 Mr. Heinemann, Municipal Engineer, prepared a scheme for supplying the whole demand of Ajmer for water from the Sagarmati Valley, and from that report the following abstracts are made:—

"Report on the proposed Improvement of the Ajmer Water-supply.

1. The necessity of the scheme.

"Ajmer is situated in a horse-shoe valley at an elevation of 1,600 feet above the sea. The outflow from the valley to the south eventually finds its way to the Indian Ocean, while that from the country beyond the northern hills passes to the Bay of Bengal.

"Ajmer may therefore be said to form a portion of the great Watershed of India. This being the case, it is obvious that practically no water can flow into Ajmer, there being only a small catchment area above the valley.

"In this small catchment area two lakes have been formed, the Anasagar and the Foysagar.

"On these lakes, Ajmer has in the main depended for water, the only other source of supply being the small natural lake at Budha Pushkar, where a pumping plant was installed by the R.-M. Railway in 1899-1900.

"The Anasagar water is only used for gardens and Dhobi Ghats.

"All these sources of supply are very precarious, the catchment being small and the rain-fall most precarious. Appendix X gives the annual rain-fall and storage of the Foysagar lake.

"The loss of water by evaporation in the dry climate of Ajmer is on an average 5 feet per annum, and the amount of water lost by evaporation is a very serious consideration.

"With the increase of the population of Ajmer the consumption of water has risen from 99·94 million gallons per annum in 1897-98 to 257·66 million gallons in 1907-08, and it is only with the greatest difficulty that these increasing demands can be met even in years of plenty.

"In 1907 the lack of water had become acute, and Mr. Goodwin, Loco. Superintendent, Rajputana-Malwa Railway, strongly advised the removal of the Rajputana-Malwa Railway Workshops from Ajmer.

"Although this proposal would have entailed an expenditure on the part of the Railway of a sum of between 50 to 100 lacs of rupees, in the face of the constant recurring scarcity of water which on each occasion was becoming more acute, the Home Board were prepared to sanction the scheme if no adequate supply of water in Ajmer could be found.

"The removal of the Workshops from Ajmer would have been an incalculable loss to the place.

"In these circumstances every effort was made to find a certain supply of good water.

"In April 1907 Mr. E.W. Vrendenburg of the Geological Survey of India visited Ajmer and reported on the possibility of various sources of supply (*vide* Appendix V).

"In May 1907 the late Mr. A.E. Silk, Sanitary Engineer of Bengal, visited Ajmer and made various suggestions and recommendations (*vide* Appendix VI).

"By the 25th July the position of affairs had become most critical, as no water had been received in the Foysagar and Anasagar, and the total amount of water available for supply was reported by the Executive Engineer, Ajmer Provincial Division, to be not more than sufficient for two months. On the 18th August 1907, 5·45 inches of rain fell, and the Foysagar overflowed, and Ajmer was saved the horrors of a water famine.

"Although this timely andu nexpected fall of rain saved the situation for the time being, there always remains the fear that on another occasion such good fortune may not happen.

* * * *

2. The possible sources of supply.

"The possible sources from which an adequate supply could be obtained, were found to be either the Sarsuti River Valley or the Sagarmati River Valley. The main features of the latter are commented on in Mr. Heinemann's Report on the tests carried out during the past hot weather (Appendix VIII).

"The Sarsuti Valley lies beyond Budha Pushkar and is a wide cultivated valley with a steep barrier of hills on the west.

"On the eastern side it is also enclosed by hills until just south of Budha Pushkar; beyond this point the rocky hills disappear below accumulations of driven sand which form the eastern boundary of the valley.

"Borings put down in this valley along the river bed show the rock substratum at a very even level but no great depth of water.

"A spring with artesian conditions was found near Galti, but both Mr. Vrendenburg and Mr. Silk were of the opinion that no safe supply could be obtained from this point, owing to the very small catchment this spring could have.

"The result of the investigations in this valley goes to show that there is water in considerable quantities in it, but not so much as in the Sagarmati Valley. The nearest point to Ajmer from which a safe supply could be obtained is near the village of Nand.

"This point has practically no gain in distance over the proposed site of the water works in the Sagarmati Valley, and all water would have to be pumped over the Pushkar Pass; this and the fact that all materials, fuel and stores would also have to be carted over this pass would make the cost of working much heavier than in the Sagarmati Valley, where the Railway is only about 5 miles from the site of the works.

"Full particulars of the test carried out in the Sagarmati Valley will be found in (Appendix VIII).

3. Estimated quantity of water available.

"The estimated minimum quantity of water available has been given by Mr. A. E. Silk (*vide* para. 3 of his report, Appendix VII), as 1,300 million gallons per annum or our two years' supply at the maximum rate of 16,00,000 gallons per diem. Looking at the well tests in Appendix VIII it will be seen that when the test was started at the end of May 1908, the water level in the trial well No. 37 was 7·64 feet.

"In the section of the bore holes which accompanies that report the water level was 8·00 feet. This water level was recorded in January, so the total fall in the water level from January to May was only 0·36 feet. Notwithstanding that heavy cultivation was going on in the valley, quantities of water were also being pumped out during the well-sinking in April and May.

"From this it appears that there must be a considerable flow of subsoil water into the valley.

"Again, looking at these tests it is found that the lowest level of the water in the well before pumping commenced (at 7 A.M.) was 6·97′ or a fall of 0·67′. A good deal of irrigation was going on from the neighbouring cultivators' wells at the same time, and this was also a drain on the water of the valley.

"Taking all these figures into account, and also the fact that it is said that even during the worst famines the cultivators' wells in this valley have never failed, there seems no doubt that an ample supply of water is obtainable from the Sagarmati Valley.

"In addition to this the natural formation of the valley just west of the site of the water works makes it possible for this amount to be materially increased if necessary at a later date, in the following manner.

"Just west of the site the rock substratum of the valley rises in some parts to ground surface, and all across to within a few feet of the ground.

"If a concrete or masonry wall were built along this ridge to ground level it would prevent any subsoil water passing away from the valley and thus raise the subsoil water level.

"Again, should this accumulation of water require further augmentation an earthen bund a few feet high thrown across the valley along the alignment of the concrete wall, would prevent the surface water flowing past when the Sagarmati River comes down. The usual flood depth is between 3′ and 4′, and the duration of the floods seldom exceeds a few hours. The water so held up would percolate into the sandy soil of the valley and be stored under-ground for future consumption.

"There would therefore be no loss by evaporation.

"However, both these proposals are only put forward to show how at a future time the supply can be increased, and not for immediate consideration, as there is at present sufficient water available for all requirements.

4. Present supply and allotment.

"The quantity of water delivered to Ajmer on an average of the past three years from the Foysagar and Budha Pushkar was 240·66 million gallons per annum or 660,000 gallons per day.

"The allotment of the supply was :—

	Gallons.
City or stand post supply	396,203
Railway	190,073
Mayo College	20,169
Merwara Battalion	7,623
Private consumers	55,932

"The quantity of 396,203 gallons supplied to the city may be taken as used by the inhabitants of the city proper only, as the suburbs are not yet supplied with a standpost supply.

"The population in the city proper in 1901 was 52,000, therefore this supply amounts to 7·66 gallons per head, but at least, 22,000 people obtained no supply at all, although paying equal taxes."

2. The scheme worked out by Mr. Heinemann was briefly to obtain 16,00,000 gallons of water per day from the Sagarmati Valley, and to *substitute this for the present supply* at a cost of Rs. 10,54,000.

The Municipal Committee, however, found that it would be difficult to finance this scheme, and did not feel fully assured that the supply was forthcoming from this source. They therefore asked Sir Swinton Jacob, whose local knowledge of the water-supplies and sources in Rajputana is unique, to inspect the valley and advise them.

450 g/m " 6,48,000 in 24 hrs
520 " " 7,48,800 " "

Note

If more water than the 5 lakhs is required & ~~perhaps~~ with one ~~perhaps with both~~ pumps we cd pump $7\frac{1}{2}$ lakhs into Ajmer by shutting off Ajaypal tank in 24 hours

Ajaypal Reservoir to City Tank = line 42,000' of 10"

$750000 \text{ G/d}_{24\,hrs} = 520 \text{ G/m}$

Head req.d 3.3 ‰ 1:ft or	139'
Level of Mayo Gate cistern	325
Head req.d at Ajaypal	464'
Actual tank f: s: " "	436
Extra head.	28' only

This extra head cd easily be pumped by the plant. & this extra head shd not endanger the pipe line.

His report is attached (Appendix XI).

Upon the face of this report the Municipal Committee were nervous of investing such a large sum, and Sir Elliot Colvin, Agent to the Governor-General, directed that further experiments should be made during the summer of 1912.

These experiments were carried out and are given in Appendix XII.

But after very careful consideration of the Geological formation and the peculiar position of Ajmer on the water-shed of India, where there are no natural springs or known subterranean supplies, and where the water supply available is only the drainage of a limited area of little depth of sand and gravel lying on rock, I consider that it is only actual experience of pumping the full supply required for a series of years culminating in years of bad or no rainfall, that will make it certain whether the supply in the Sagarmati Valley is sufficient to cope with the *full* requirements of Ajmer.

But we have Mr. Heinemann's Report, our experiments in 1912, Messrs. Vrendenburg's and Silk's Reports, and the knowledge that even in a series of bad years ample water for irrigation is available.

3. My proposal, therefore, is to provide a water-supply to *augment the present one* when it begins to, or threatens to, fall short of requirements.

And to be such a scheme that if after several years' practical test during years of light or no rainfall in that valley it is found ample, the supply may be increased in size, and if so wished developed into a scheme to supply Sagarmati water alone to the city for drinking purposes, in lieu of the present tank water and the now proposed combined scheme.

It might later, if necessity arises, be considered whether the Foysagar supply should not be filtered.

I propose to pump 500,000 gallons per day of 16 hours, which will gravitate to the city reservoirs in 20 hours. But if urgent necessity arises and there proves sufficient water, by pumping the whole 24 hours and using the existing 12" main from the Foysagar to the city reservoir 750,000 gallons can be supplied.

The Budha Pushkar can be relied upon for 450,000 gallons a day; the plant *has* delivered 500,000 gallons per day.

So we should have plant sufficient to deliver 1,200,000 gallons per day without the assistance of the Foysagar, which is the amount Mr. Heinemann estimated the requirements in 1921 might amount to.

For the present I propose this Sagarmati scheme to be used as a "stand-by," because it is naturally cheaper to run water by gravitation

from the Foysagar when available than to pump it up from Sagarmati. The plant should, however, be used for a month every year regularly to keep the same in trim.

4. In this estimate I propose no alteration in the present distribution system. If we find that after pumping during 'bad' years the valley *can* supply us with more than 500,000 gallons daily now proposed to be pumped, the scheme *can* be extended by increasing the number of wells *as* required, and by putting on a third pump, in fact duplicating the whole system with the exception of having three pumps instead of two, at a cost of roughly *Rs. 4,39,085 with establishment charges or Rs. 4,12,327 without.

A further economy could be effected if the present pipes from Foysagar to the city tank be used to bring in the Sagarmati water, but then we should not be able to run both Foysagar and Sagarmati water at the same time into the city tanks.

5. Briefly described my scheme is:—

(1) To have eight fifteen feet diameter wells across the main valley at Masina sunk to the stratum of kunker, which substratum will be pierced to tap the subsoil water. This number of wells can be increased to 16 should more water be required or the yield of each well fail.

(2) These wells linked together by suction pipes terminating in a suction chamber placed in a central position at the engine house, the suction pipe being laid in a masonry tunnel. This system has been adopted with success at Amritsar, Ludhiana, Lahore, etc.

(3) Two pumps and boilers, each capable of pumping 520 gallons a minute or 500,000 gallons in 16 hours to the top of Ajaipal Ghat, through a 10″ pipe.

(4) Accommodation for the necessary staff.

(5) On the top of Ajaipal Ghat a tank capable of holding half a day's demand, so that if the demand for the tanks in the city be irregular, the water could be accumulated there and run off into the city tank as required. In fact this will be what is known as a balancing tank, and would be of use to store water during any necessary repairs to the delivery pipe.

(6) A delivery pipe from the tank to the city Reservoirs. This will be of 9″ and 10″ piping. 8,000 ft. of 9″ piping is now held by the Municipality, which I have thus brought into use.

H. C. SANDERS,

4th February 1913. *Superintending Engineer, Rajputana.*

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*See Appendix, II.

Storage available

Existing

Naya gate reservoir	N. 1	21,102 cft.	
" "	N. 2	19,793	
Delhi gate "		5,730 cft	2,91,406 g:
Ry.	N. 1	32,820	
"	N. 2	31,970	4,04,938 g:
		111,415 cft	
		= 6,96,344 gallons	

Ajaipal
$D = 58.42'$
Depth $= H = 10$
Contents 26,710 cft or 1,66,670 gallons

8,63,014 gallons

~~500,000 g/d ÷ 2 = 250,000 g~~
~~= 40,000 c: ft:~~
~~Tank 10' deep area ∴ = 4,000 s: ft~~
~~⊙ 71.4' diam:~~

City reservoirs, (1) Delhi gate
(2) Naya "
(3) Railway (1)
(2)

Total storage Munic:
Ry :

APPENDIX I.

SAGARMATI WATER-WORKS FOR AJMER.

Detailed History.

Abundant amount of water available.

Since the year 1906, when the importance of the question of providing a sufficient supply of pure water for the City of Ajmer was first brought to the notice of the Local Municipal Committee, Geological, Sanitary and Engineering experts have thoroughly explored the neighbourhood of Ajmer, and have unanimously come to the conclusion that the Sagarmati Valley, near Bhaonta, is the place where an abundant supply of water fit for potable purposes can best be obtained.

Mr. E. W. Vrendenburg's Report, April 1907. *Vide* Appendix V attached.

From a Geological point of view Mr. Vrendenburg says: "..............Trial excavations might be made to get some idea of the rate of flow, but there is no doubt that at this place there is enough water to supply many times the needs of Ajmer..............and I am under the impression that it is the best supply in the neighbourhood of Ajmer.............." (para. 22).

Again: "Conclusion. The Valley of the Sagarmati below Ajmer constitutes the area most likely to yield a considerable addition to the present water-supply of the city" (para. 24).

Finally he says: "I should like to know the results of a test of the river bed opposite Masina But even without such a test, I have no hesitation in stating that it contains much more than is needed for Ajmer ...." (para. 27).

Mr. Silk's Report, January 1908. *Vide* Appendix VII attached.

Mr. Silk, Sanitary Engineer, Bengal, first visited the place in 1907, and made some suggestions as to how to investigate the matter, and when the valley of the Sagarmati had been explored in the manner he suggested, in the following year he again visited the place and carefully examined the Sagarmati Valley between Dumara and Masina, and expressed his views as follows:—

"..................The Catchment area of the Sagarmati up as far as Masina has been ascertained to be 90 square miles, and if an inch of rain fell on this area and was absorbed into the ground a volume of 1,300 million gallons would flow underground past Masina during the year. From the rainfall records of the past 21 years, it is found that the annual rainfall at Ajmer has only been less than 10 inches on two occasions, *i.e.*, 1891 and 1905. In most years, however, the rainfall is considerably more than 10 inches, and it will thus be seen that if we assume that only one inch of rainfall in each year is absorbed into the ground or less than 10 per cent., there will be considerably more water available in wells at Masina than will ever be required for the supply of Ajmer" (para. 3 of the letter, dated 11th January 1908).

Here Mr. Silk estimates the minimum quantity of water available as 1,300 million gallons per annum, which is over 7 times the present requirements at the rate of 500,000 gallons a day or 182½ million gallons per annum.

Mr. Heinemann's Report, July 1908. *Vide* Appendix VIII attached.

After making necessary tests by means of a trial well ("old test well" in Mr. Cantin's report) in the bed of the Sagarmati Valley, in accordance with the instructions from Mr. Silk, Mr. Heinemann drew the following conclusions:—

(*a*) Fall in the subsoil water level of the valley, at the site of the test well, from January to May was only 0 36 feet or about 4¼ inches, notwithstanding the heavy cultivation in the valley and the amount of water pumped out during the sinking of the well in April and May.

(*b*) Taking the trial well alone it can be seen that on May 27th at the beginning of the test the water level stood at the reduced level of 7·64 and sank to its lowest level 6·97 on the 19th June. That is to say after 21 days' pumping, during which time 900,000 gallons of water were pumped out, the water level in the well was only reduced 0·67 feet or 8 inches. A good deal of irrigation was still going on on the neighbouring wells, which was also a drain on the water of the valley.

NOTE I.—First, this must be specially noted that these observations were in the hottest period of the year when (*a*) spring level naturally reaches its lowest and (*b*) when water is most needed for cultivation, etc.

II.—Secondly, this small quantity of 900,000 gallons of water pumped out during the days of May and June is quite insignificant when compared with the probable amount of water that might have been drawn by cultivators from their wells fed by the subsoil water of the valley, for irrigating their fields. For an acre of cultivation needs 60,000 C.ft. of water (3¾ lakhs gallons) to get it fully reared, and that the irrigation continues for about 60 working days throughout the age of the crop, a daily supply of 1,000 C.ft. or say 6,250 gallons water would be needed for an acre. Therefore during 21 days one acre needs 131,250 gallons of water. And the total amount of water pumped from the test well was hardly equal to the requirements of 7 acres of cultivation, while such cultivation in the valley is far more extensive.

What of that, even the total quantity of water now proposed for the City of Ajmer at 500,000 gallons a day or 182·5 million gallons or less than 30 M. C.ft. per annum, would be only able to irrigate about 500 acres or ⅘rd of a square mile of cultivation for one good crop (60,000 C.ft. of water irrigating one acre).

(*c*) From this, it appears that there must be a very considerable flow of subsoil water into the valley.

(*d*) Taking all these figures into account, and also the fact that, it is said that even during the worst Famines the cultivators' wells in this valley have never failed, there seems no doubt that an ample supply of water is obtainable from the Sagarmati Valley.

Again Mr. Silk.

After going through the tests made by Mr. Heinemann, results of which have briefly been explained above, Mr. Silk, in his letter, dated the 29th September 1908, writes: "I state here that in my opinion the results obtained by the well experiment show clearly that there is ample water in the Sagarmati Valley for supplying Ajmer."

Sir Swinton Jacob's views, April 1910. *Vide* Appendix XI.

In an extraordinary meeting of the Ajmer Municipal Committee it was suggested that the opinion of Sir Swinton Jacob, who was well acquainted with the local conditions, might with advantage be obtained on the question whether the Sagarmati source would afford a permanent supply of water.

Sir Swinton, accompanied by the present Superintending Engineer, visited the Sagarmati Valley on the 5th April 1910 and expressed his views:—

(*a*) Commenting on what Mr. Silk says in (para. 3) of his letter* dated the 11th January 1908, Sir Swinton observes "......what guarantee is there that even if $\frac{1}{10}$th of the rainfall is absorbed in the ground, that it will all reach the well area, and not find its way by gaps or fissures in the subterranean rocks, to a lower level?" (Para. 6 of his Note).

(*b*) Reviewing Mr. Heinemann's statement that "even during the worst Famines it is said that the wells in the Sagarmati Valley have never failed" he (Sir Swinton) says: "This may be quite true, but it is not stated how much water was drawn. It is possible it might be different, if powerful steam pumps were employed continuously." (Para. 8 of his Note).

(*c*) Then he says: "......what proof is there that with such a constant demand, the yield obtained from a 6 feet well, for 40 days or so, will be constant and continuous for any length of time in this, or in other wells ?......actual trials, which should be made under circumstances truly representing the conditions required. The tests ought to be more severe, even than what will actually be required, so as to have a good margin for safety." (Paras. 9 and 10).

(*d*) Finally he says: "Taking all these points into consideration, although there is great probability that the Sagarmati Valley will yield a sufficient quantity of water for the

* Appendix VII.

> anticipated needs of Ajmer during years of scanty rainfall, I do not consider that the tests have been sufficient to prove it." (Para. 12).

In view of Sir Swinton Jacob's opinion, briefly expressed above, in the ordinary meeting of the Committee held on 17th March 1911, they resolved that:—

1. "That it is inadvisable to abandon the existing Foysagar supply of water, to which the new scheme should be supplementary."

2. "......in years of normal rainfall the Sagarmati will supply water for domestic purposes to the city and suburbs, while the Foysagar will be utilized for the Railway Station and the Workshops and for irrigation. In case of failure of the Sagarmati supply the Foysagar will be available for the needs of the city and suburbs, while the Railway will, if necessary, pump their own water from Budha Pushkar. In time of famine the arrangement at present in force will hold good, *i.e.*, that the city has the first claim upon Budha Pushkar for domestic purposes only."

About the same decision, in rather more definite form, was arrived at at a meeting of the marginally-noted officials, held at the Municipal Office on 1st November 1911.

The Chairman, Mupl. Committee.
Mr. H.C.Sanders, Supdg. Engineer.
Mr. P.A.L. Cantin, Exe. Engineer.

There they were of opinion that any scheme should be auxiliary to the Foysagar, and that for this purpose a supply of 5 lakhs of gallons daily (pumping for 16 hours), would suffice, this being calculated on a minimum of 5 gallons per head on a population of 1 lakh, which might be necessary if the Foysagar entirely failed, leaving the requirements of the Railway to be met from the Budha Pushkar. Under these circumstances it would only be necessary to pump from the Sagarmati Valley for a few months in every year, except in years of exceptionally scanty rainfall. In such years from previous experience it seems clear that the Budha Pushkar may be depended upon as the last resort, and it will be reserved for this purpose.

And these considerations led the committee to think that there is a reasonable prospect that the Sagarmati supply will be amply sufficient to supplement the Foysagar in normal years or years of scanty rainfall, and that therefore additional tests are not imperatively required.

Yet last year being the year of short rainfall the Hon'ble the Chief Commissioner, in January 1912, expressed his opinion to further test the ability of the Sagarmati Valley to yield the required water by pumping the full supply required during the three months before the monsoon, carefully noting the effect on the spring level.

The tests were accordingly made by the Municipal Overseer, under the instructions and close supervision of Mr. Cantin, Executive Engineer, during the months of June and July last.

As remarked by Mr. Cantin in his report on the above tests it was proposed to sink 4 wells of 15 feet diameter and to draw 500,000 gallons daily in 16 hours during 6 months, from January until the burst of the monsoon. The proposal was, however, sanctioned in March and only 2 new wells could be sunk.

Mr. Cantin's views, August 1912. *Vide* Appendix XII attached.

In his report referred to above he says: "The conclusion to be drawn from the results is that the scheme, if taken up, will prove a success."

Discussing the geological conditions of the valley along the lines 2 and 3, he remarks that "the great fertility of the surface soil, the numerous village wells which have never been known to fail, the coarseness and the cleanness of the sub-soil, the absence of clay and silt, are very favourable and clear signs of an alluvial tract. In such a tract the sub-soil water does not flow along subterranean fissures but is contained in the saturated bed of sand, and percolates slowly through the interstices between the grains. Sand holds an enormous amount of water, as much as 40 per cent., and in alluvial plains the supply is almost inexhaustible. For a percolation well to be a success the sand must be clean and coarse, and these conditions are fulfilled by the water-bearing stratum at Bhaonta."

As regards the results of his tests it can be said that they go more towards the fixing of site, safe yield of each well and therefore the number of wells required, than to prove the ability of the source any more than the tests made before them.

The yield of well No. 1 (new trial well, 15 feet diameter), by recuperation tests, has been found to be 162,000 gallons per day of 16 hours under the working head of 4 feet.

And the yield of well No. 2 (new trial well, 15 ft. diameter), by same tests has been found to be 115,000 gallons per day under similar conditions.

The difference in the yields of these wells was due to the fact that the latter was sunk where there was less thickness of sub-soil and bed rock closer to the surface than in the case of the former.

And considering the aggregate yield of these 2 wells (*i.e.*, 277,000 gallons a day), four such wells in all, would more than do for the present requirements.

But in order to affect the spring level in the wells least, and to lessen the drain on each well, it would be advisable to have a double set of wells on which to draw steadily but under a less head.

The total amount of water pumped out during the operations from the wells No. 1 and No. 2 is 5,092,850 and 2,915,360 = 8,008,210 gallons respectively, during the period from 9th June 1912 to 28th July

1912, excluding the quantity of water that was pumped out during the process of sinking the above wells.

Averaging 204,091 gallons a day,—from No. 1, 115,747 + 88,344 from No. 2.

Effect of pumping on spring levels in the test wells and wells adjoining them was observed as given below :—

NAME OR No. OF WELL.	Water level on 12·6·12, when pumping was first started below ground.	Lowest water level during test operations.	Total fall in inches.	Date of such fall.	REMARKS.
Well No. 1 ...	9′-10″	10′-8″	10″	7-7-12	It remained stationary till 16-7-12 and then began to rise when rain fell.
Well No. 2 ...	12′-7″	13′-0″	5″	Do.	Do.
Old test well ...	8′-0″	8′-10″	10″	Do.	Do.
Well near old well	10′-0″	10′-10″	10″	Do.	Do:
Madho's well ...	12′-0″	12′-10″	10″	14-7-12 and 25-7-12	
Umra's well ...	14′-3″	15′-1″	10″	9-7-12	It remained 15′-0″ till 17-7-12.
Goma's well ...	12′-9″	13′-8″	11″	8-7-12	It remained stationary till 19-7-12.
Well A	13′-3″	14′-0″	9″	5-7-12	It remained stationary till 16-7-12.
Dolsing's well ...	7′-1″ on 3-7-12	7′-3″	2″	8-7-12	It remained stationary till 20-7-12.
Bhairon Bukh's well	7′-9″ on 8-7-12	7′-9″	*Nil.*	16-7-12	Then begins to rise.

This fall is not more than might be expected as due to the hot season and not to the water drawn out mechanically.

It would not be out of place to mention here that again these tests were made during the hottest period of the year and when the heavy cultivation of maize and cotton on the banks and of water-melons in the bed of the river, was being irrigated at the same time.

H. C. SANDERS,

Dated 4th February 1913. *Superintending Engineer, Rajputana.*

ENCLOSURE TO APPENDIX I.

A copy of the Chemical Analysis of the water is given below.

Two samples were sent for analysis, one taken directly from the well (old trial well, I think) and from the discharge of the pump.

Copy of label on Bottle.	Total solids grains per gallon.	Chlorine grains per gallon.	Total hardness grains per gallon.	Fixed hardness grain per gallon.	Free ammonia parts per million.	Albomided ammonia parts per million.	Nitrites.
Water from well.	49	7·5	11·5	5·5	0·04	0·04	*Nil.*
Water pumped from well ...	48	7·2	11·5	5·5	0·01	0·03	*Nil.*

Both of the above water samples are fit for potable purposes.

H. C. SANDERS,

4th February 1913.

Superintending Engineer,
Rajputana.

APPENDIX II.

Estimate of Cost of Duplicating Plant.

	"England."	"India."	Total.
	Rs.	Rs.	Rs.
(1) Head Works Item 4	...	26,440	26,440
" 5	8,380	2,091	10,471
" 9	...	7,091	7,013
" 10½	37,700	...	37,700
" 11½	...	5,000	5,000
	46,080	10,544	86,624 (A)
(2) Rising Main	2,19,463	63,688	2,83,151
Deduct item 2	...	6,000	6,000
	2,19,463	57,688	2,77,151
Add 6,000′ of 10″ 8″ pipe ...	23,134	5,783	28,917
	2,42,597	63,471	3,06,068 (B)
Total of (A) and (B) ...	2,88,677	1,04,015	3,92,682
Add 5% Contingencies ...	14,434	5,201	19,635
Total Cost ...	3,03,111	1,09,216	4,12,327
Charges for Establishment 23% ...	*Nil*	25,120	25,120
" Tools and Plant 1½% ...	*Nil*	1,638	1,638
Grand Total ...	3,03 111	1,35,974	4,39,085

F.S. Ajaipal Reservoir		436.2
Level c: of Pump Piston		101.1
Lift		335.1
Calculated friction		
$\frac{20,083 \times 3.25}{1,000}$		65.3
		400.4

Pump indent — " —

Present w: surface	94.5	
Future min:	87.0	
" pumping	82.0	

Taking 87.0 as present low p: head

Suction 101.0 - 87.0 =	14'	
Friction	2.6	16.6
		417.0

Distance from ~~Pumps to Reservoir 20,083' say 20,100'~~

Friction 65.3

Actual Lift [illegible]

[illegible]

APPENDIX III.

Pipes, Friction and Power.

Supply to be 500,000 gallons a day of 16 hours.

Equivalent to $\frac{500,000}{16 \times 16}$ gallons a minute = 521 g/m.

(Note --Friction calculated by Baines' slide rule).

Suction Lift for Pumps.

From 8 wells ·65 gallons a minute from each well :—

		Pipe.	Discharge.	V.	Loss of Head %o feet.	Loss of Head.
For	206′	5″	65 g/m	1·3	2·4	·48
	206′	6″	130 g/m	1·8	3·2	·64
	206′	7″	195 g/m	2·0	3·2	·64
	206′	8″	260 g/m	2·0	2·8	·56
Each well	36′	4″	65 g/m	2·0	6·6	·25
						2·57
				Actual lift		ϕ 18·00
						20·57 feet.

ϕ Pump level	R.L.	100·00
Present water level		92·00
Possible future water level		87·00
Pumping head		82·00

Rising Main.

520 g/m to be lifted in 10″ pipe :—

Delivery pipe at Reservoir	R.L.	428·00
Engine delivery		100·00
Actual lift		328·00

Distance	22,350′	
Velocity	2·6′	
Loss of head per %o	3·25′	
Total Loss of head 22·35 × 3 25		72·64
Total		400·64 feet.

Total Work for Pumps.

Lift	20·6′
Rise	400·6′
Total lift	421·2′

1 gallon weighs 10 lbs.

Actual work for pumps ... $\dfrac{(\overset{g/m}{520} \times \overset{lbs}{10}) \times \overset{ft.}{421 \cdot 2}}{33{,}000}$

$= \dfrac{21{,}902{,}400}{33{,}000}$

$= 66 \cdot 4$ H. P. actual.

Delivery from Reservoir to Tanks.

	Pipe.	Length.
22,350′ to 31,115′ ...	... 10″ ...	... 8,765′
31,115′ to 39,115′ ...	... 9″ ...	... 8,000′
39,115′ to 56,715′ ...	... 10″ ..	... 17,600′

We shall pump at rate of 520 g/m in 16 hours and deliver the same in following pipes:—

8,765 of 10″	equivalent to	8,765 of 10″ pipe
8,000 of 9″	,,	,, 13,680 ,, ,, ,,
17,600 of 10″	,,	,, 17,600 ,, ,, ,,

equivalent to 40,045 ft. of 10″ pipe.

Total fall 100·5 into Naya Gate Tank or $2\frac{1}{2}$′ per ‰ delivery is therefore 450 g/m.

Into Delhi Gate the fall is 80·5 only or 2′ per ‰ delivery is therefore 400 g/m.

About $\frac{1}{5}$″ of the supply is required in the latter, so 440 may be taken as the average discharge, thus the 500,000 gallons would be delivered during 20 hours, or the pipe could deliver 630,000 gallons in the 24 hours.

If the existing 12″ main from Foysagar be also used, the discharge of the pipe = 565 g/m.

The pressure at different points of the line will be as follows:—It is never excessive beyond 9,000′.

	R. L. of Hydraulic Pressure.	Ground.
At 0′ ...	... 500·64 ...	... 100·00
9,000 ...	... 471 39 ...	... 175·97
22,350 ...	... 428·00 ...	... 428·00
31,115 ...	... 406·1 ...	... 372·00
39,115 ...	... 371 9 ...	... 337·80
56,715 ...	... 327·9 ...	... 327·5

The pressure between 0′ and 9,000′ for ordinary 10″ pipes of $\frac{9}{16}$″ thickness is a little high, and it is advisable to increase them to $\frac{5}{8}$″ thickness in this reach.

In no other place is the difference of level excessive.

Without steaming

Actual discharge 8.4.15

done at av. of 4.7¼" 30,000 g/h

Actual into Delhi System

done at av. of 3.2¼" 32,800 g/h

into Naya Tank

or taking av. of 32,000 g/h

7½ lakhs g/24 hrs.

Variation in discharge when Tank is full & when empty is 5% calculation.

Delivery Pipe					Equivalent 10"
from 20,~~000~~ 100	to ~~22,953~~ 23,953	10"	~~2,656~~ 2,870		2,870
from	to ~~35,729~~ 36,007	9"	~~12,990~~ 13,054	×1.7 =	22,092
from ~~35,729~~ 36,007	to 53,1~~45~~ 115	10"	17,138		17,138
	say ~~53,400~~		33,062		~~42,208~~ 42,200

Total fall

Full supply in Reservoir

Delivery pipe Naya Tank

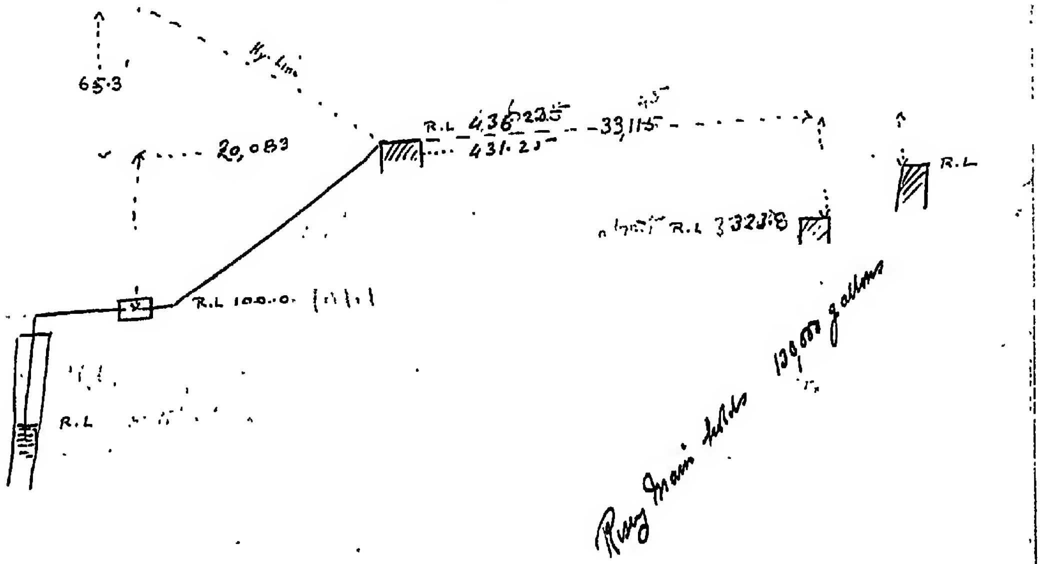
" " Delhi

Available fall

Delivery

Fall per 1000' of 10" pipe Naya Tank = ∴

Delhi = ∴



4 lbs of coal per HP hour
or about 2 Tons a day

M.Hd Eng[illegible] gives

Initial cost at	~~5~~ 4 %	on	5,31,000	21,240
Ince Machinery	5	"	78,000	3,900
Pipes	2½	"	2,78,000	6,950
Bgs	2	"	96,000	1,920
				34,010
Working Expenses per year		"		18,000
Supervision	"	"		4,500
Total				= Rs 56,510

Qty pumped per year ~~Rs~~ gallons = 180 mig: ~~[illegible]~~

Cost per thous: gallons 5.01 annas

Supt		165
Driver		40
Asst "		30
Oilman	4 @ 9/-	36
Fireman		15
		12
Coolies	3 @ 8/-	24
Chok		8
Lineman		15
Messenger		8
Peon: Clerk		7
Sweeper		6
		Rs 390 =

APPENDIX IV.

MAINTENANCE EXPENSES.

Permanent expenses, *i.e.*, during all twelve months:—

Assistant Driver	Rs. 40	
Chokidar	„ 7	
Sweeper	„ 6	
Linesman	„ 10	
Petty purchases	„ 15	
		Rs. 78 a month.

= Rs. 936 a year.

Expenses during pumping (sixteen hours a day) in addition to above:—

Driver	Rs. 100	
Oilmen, 2 @ Rs. 9	„ 18	
Head Fireman	„ 15	
Assistant Stoker	„ 11	
Coalmen, 2 @ Rs. 8	„ 16	
		Rs. 160 a month.
Coal 200 lbs. per hour (16 hours a day) = 1·4 tons a day, or 43·4 tons a month @ Rs. 20 a ton ...	Rs. 868	
Oil and sundries at 10 %	„ 87	
		Rs. 955 a month.
Total pumping charges ...		„ 1,115 a month.

ANNUAL REPAIRS.

To plant @ 2 %	Rs. 1,508	
To buildings	„ 492	say
		Rs. 2,000 a year.

If water be pumped 3 months a year or for 92 days, *i.e.*, 46,000,000 gallons, it will cost Rs. 936 + Rs. 1,115 × 3 + Rs. 2,000 = Rs. 6,281 a year, or 2·2 annas per ‰ gallons.

APPENDIX V.

Report on the Possibility of Improving the Water-supply of Ajmer.

By Mr. E. W. Vrendenburg, Geological Survey of India, dated 11th April 1907.

1. I arrived at Ajmer on the 5th of April, and reported myself on arrival to the Commissioner of Ajmer-Merwara, Major C. H. Pritchard, to whom I feel deeply indebted for the efficient assistance which he constantly gave me in investigating the question of the water-supply of the city of Ajmer.

2. On the morning of the 6th, the Executive Engineer, Pandit Sham Nath, Rai Bahadur, accompanied me over the upper valley of the Sagarmati, from the Foysagar to the Bisla tank. In the afternoon I attended a meeting of the General Committee at the Town Hall. On the 7th in the morning, Mr. Waddington, Chairman of the Municipality, very kindly showed me the valley of the Sagarmati below Ajmer as far as Dorai. In the afternoon I was accompanied by the Tahsildar to the valley of Madarpura and to Kirnnipura. On the 8th I visited the valley of the Sagarmati below Dorai up to Bhaonta. On the 9th I visited the Budha Pushkar lake and the valley of the Sarsuti from Galti to Ganahera. On the 10th I visited the Kair tank. During these three days I was accompanied by Pandit Sham Nath, who has gone to great pains to show me all the places of interest, and furnish me with all the information that could be of use in this investigation.

Physical and Geological Features.

3. The structure of the neighbourhood of Ajmer is that which characterises the Aravalli region: a number of parallel ridges running north-east and south-west, separated by broad valleys.

4. Geologically the region is constituted by the quartzites and schists of the Aravalli system, forming a series of highly-compressed parallel folds. The ridges consist principally of quartzite which, owing to its hardness and inalterability, resists disintegration better than the schists of various sorts constituting the intervening valleys. It is not possible to say in the present stage of our knowledge regarding the geology of the region whether the quartzites of the successive parallel ranges are repetitions of one band, or separate bands occurring at different geological horizons. The rivers are mostly disposed longitudinally along the flat valleys separating the parallel ridges. The altitudes of the valleys relatively to one another do not differ much, and these differences do not follow any particular law, as the general slopes of these valleys may be in one direction or the other, according to the direction of drainage. For instance one river may be flowing north-eastward in one valley, while in the adjacent one it may be flowing south-west.

5. A structure such as the one above outlined is unsuited to the existence of artesian conditions. Artesian conditions require that a particular porous bed should outcrop over a fairly large area and from there descend beneath a lower lying region under an impermeable covering.

6. The primary conditions for an artesian supply are wanting. The compact rocks of the Aravalli formation, except where decomposed in the neighbourhood of the surface, are not porous, and can only become water-bearing as the result of fissures whose disposition is too uncertain and too irregular to justify the sinking of deep wells. Although the strata out-cropping in certain valleys may sink beneath the floor of another valley whose surface is at a lower altitude, the small difference of altitude from one valley to another, the compactness of the strata and the absence of regular alternations of beds of different degrees of porosity, absolutely condemn all reasonable chances of obtaining a large supply of water under pressure from great depths. The hills consist of rocks that are no more porous than those of the intervening plains, and being mere narrow ridges do not in any way affect the water-bearing conditions in depth. Owing to their comparatively insignificant dimensions, and also to the lesser degree of aridity of the region, their slopes are not accompanied by the great talus of debris that skirts the mountains of Baluchistan, Persia, and Central Asia, and stores the water-supply which in those countries is tapped either by artesian wells or by the karez system.

7. The only supply of water that can therefore be drawn upon in the case of this city, is that whose upper surface is not under pressure, and which may be spoken of as "ground water." Of this, there appears to be a practically unlimited supply so far as city requirements are concerned, and the water level is everywhere at a very moderate depth. Ajmer being situated at a higher altitude than most of the surrounding country, any serious addition to the present scheme will involve raising the supply by artificial means. It seems unnecessary therefore to have recourse to the system of making artificial tanks, such as those that have already been made in the only part of the surrounding country that commands the level of the town, and whose chief recommendation is the aid of gravitation in distributing the supply. The creation of new tanks being set aside as unnecessary, the scheme that suggests itself is that in use in many other towns, of obtaining a water supply from large wells sunk where the flow of ground water is most abundant, that is in the bed of a river.

8. The two principal river valleys situated respectively east and west of Ajmer, that is the Sagarmati and the Sarsuti, appear to answer to all desired requirements. So far as I can make out from my observations, unaided by actual measurements, it is the Sagarmati that has the largest flow. The yield of the Sarsuti may be less than that of the Sagarmati; there seems no doubt, however, that it will amply suffice.

9. It is important to form a definite idea of the superabundance of water in the neighbouring district with reference to the requirements of a city. The following considerations are based upon very rough estimates, but in any case they leave such an enormous margin that any approach to greater accuracy is quite superfluous. Judging by statements made to me during the last few days, wells with a rate of percolation of some 1,200 gallons an hour will irrigate an area of some 30 bighas. One well of this capacity represents about one-thirtieth of the water-supply of Ajmer. The entire water-supply of this city, if turned to irrigation, would just suffice therefore for half a square mile. It is a well-known fact that an artesian well amply sufficient for the needs of a large city will only irrigate a comparatively small farm. This has had to be repeatedly insisted upon whenever impracticable schemes have been submitted to us as to the possibility of obviating the chances of famine by sinking of artesian wells, or other artificial means of the same degree of efficiency. Fortunately, in the present case, the argument works the other way round. In a region where a certain amount of irrigation can be carried on even during the worst droughts, the supply of a town reduces itself to selecting one amongst a number of possible schemes.

Sagarmati Valley.

10. The upper course of the Sagarmati, above Ajmer, feeds the Foysagar and Anasagar tanks, regarding which I have nothing to add to the recommendations made in the Executive Engineer's report (Proposals 4, 6, and 8 . The proposed well in the bed of the Anasagar should be made at or near the deepest part of the bed, not too near the dam, so as not to risk inducing leakage. I do not know what is the exact contour of the bed when the lake dries up, but it would be probably perfectly safe to select the lowest point situated some 500 feet from the dam. I cannot help feeling doubtful as to the quality of the water, but it could be used for watering gardens. At any rate it would be interesting, as soon as the lake dries up, to sink such a well, and pump as much water as possible from it, so as to get some idea of the length of time during which the supply could be kept up.

11. The well which is being excavated below the dam of Foysagar had not, on the day I visited it (6th April), struck any important spring. With the exception of the first 5 feet, it is entirely through rock (mica schist). The total depth on the day of my visit was 19 feet. One foot of water percolated during the night. Before ceasing to deepen it, it would be as well to find out how it compares, as regards depth, with other wells along the same valley; between Foysagar and Anasagar. Accurate measurements of the yield of these wells would be interesting. If eventually the Foysagar well yields no water, it can be converted into a convenient reservoir from which to pump the water percolating from the tank, as was suggested when it was proposed to excavate this well

12. The trench in the Beesla tank, on the day that I visited it (6th April), had traversed the whole thickness of the alluvium, and was being deepened in the underlying rock, with a very feeble percolation. The chances of striking a water-yielding fissure in compact rock are so uncertain that the experiment might probably be discontinued. The trenches excavated in the bed of the Anasagar in 1892, probably did not penetrate the rock. Before ceasing the experiment, it would be advisable to test all the wells in the Beesla tank, and find out whether their yield is proportionate to their area. If so a proportionate yield might be anticipated in the trench at the same depth.

13. There are several wells in the bed of the Beesla tank, only one of which appears to have been measured (Chitar Khan and Ballu Sheikh's well). At a depth of some 39 feet, the percolation is only about 200 gallons an hour. It is excavated through rock. The diameter is 6 feet and the yield is therefore about 7 gallons per hour per square foot of area. It would be probably useful to restore the tank and thus raise the level of sub-soil water in its neighbourhood, but its capabilities do not seem sufficient to justify much expenditure.

14. From the Beesla tank to Dorai village, the alluvium of the Sagarmati is of insignificant thickness. Just below Dorai its thickness increases considerably in the neighbourhood of the water-course, and from there, down the valley, it constantly increases in importance till it joins the great alluvial spread of the Banas.

15. Between the 4th and 5th milestone from Ajmer, less than ½ mile from the road, on the western side, there is a large well belonging to the village of Somalpura, excavated in rock (a very hard, compact hornblendic schist). At a depth of about 58 feet, the percolation is more than 2,500 gallons an hour. Fourteen wells of this capacity would suffice for the maximum requirements of Ajmer. The well is of very large size, with a diameter varying from 30 to 32 feet. The yield per square foot of area is therefore only about 3½ gallons, that is just half that of the well measured in the Beesla tank. The Somalpura well is said to have been in existence for the last 20 years. Its yield was originally much smaller than at present, the original depth being also much less. It dried up or nearly dried up in the drought of 1900, and was then deepened, with the result of a considerably increased yield.

16. There are several other wells in the immediate neighbourhood of the one just mentioned, none of which are as good, according to verbal accounts These cannot be relied upon without actual measurement, and the size of these wells must also be taken into account. It is as well to keep in mind that the yield from a compact rock such as the one at Somalpura varies greatly from place to place, depending largely, as it does, upon fissures whose position cannot be anticipated In the present case, the alluvial area which commences opposite the 5th mile near Dorai, will probably be found more suitable.

17. I was shown a well situated south of the village of Dorai, close to the bed of the Sagarmati. Its total depth is 40′·5″, entirely through alluvial formation. The greater part of the depth is through loose soil and pebbles. At the bottom there is a layer of "kankar," which is a compact calcareous conglomerate, also belonging to the alluvial formation. I have not measured the diameter of the well It is much less than in the case of the one at Somalpura. It would be important to test this well, and if the result is favourable, it may not be necessary to go any further down the valley of the Sagarmati for a water-supply. Other experimental wells might be sunk in this same neighbourhood, either in the actual river bed or quite close to it. When I saw the well on the morning of the 7th, it was being worked. It contained 11 feet of water, and a considerable flow of excellent water was running down the irrigation channel.

18. Before reaching the 6th milestone, there is a large "baoli" whose total depth is 53′-4″. It is largely excavated through rock (pegmatite). It contained 18′-10″ of water when I saw it on the 7th. It is said to irrigate an area of 37 "bighas" yielding three crops, and not to be affected by dry years. The quality of the water seems excellent. Its percolation should be tested. It is situated at a distance from the bed of the Sagarmati and at a higher level.

19. South and south-east of Dumara is a very extensive flat area, entirely under cultivation. There are numerous shallow wells in which the water is slightly brackish, though fit for irrigation. The flatness of the area and indecision of the drainage probably account for the gradual accumulation of salt. The wells are entirely through alluvium.

20. Good water is yielded by a well (Hari Singh's) situated west of Dumara on rising ground north of the Sagarmati. Although it is situated some distance up the slope leading up to the hill yet it does not reach the rock, being sunk through sand and soil, upon a wooden curb, to a depth of over 45 feet. From a geological point of view, it is therefore the only well that I have seen in this district which somewhat approaches the conditions of the karez wells in the great talus slopes of Baluchistan. The scale of the talus and the yield of the well are, however, both insignificant when compared with similar features along the north-western frontiers of India. The percolation is a great deal over 1,000 gallons an hour at a depth of 42 feet. (See detailed statement by Executive Engineer). The diameter is 19 feet, and the percolation therefore some 4 gallons per square foot in an hour. The level of the water on the day of my visit (6th April), was 36′-3″ below surface. The well is said to be out of repair.

21. As one descends from this well southwards or south-westwards towards the Sagarmati, the relative depth of the ground water, surface becomes rapidly shallower. In this neighbourhood I was shown several wells yielding excellent water. One belonging to Bur Singh and Bijai Singh, with a total depth of only 22 feet, is said to irrigate 64 "bighas"

yielding two crops. As it has four "charas" fitted on to it, these statements are probably not exaggerated. All these wells, some of which appear to belong to Dumara and some to Masina village, should be carefully tested.

22. North of Masina, as marked on the map, the sandy bed of the Sagarmati expands considerably and everywhere contains water up to 1 or 2 ft. from surface, the actual surface being moist in many places. The water looks and tastes very pure. The river-bed is at present being planted with melons. By the time the Sagarmati has reached this point, its drainage area has become considerable, probably not less than 70 square miles. Its valley is, at this place, narrow, and occupied to a great extent by the actual river-bed. Trial excavations might be made to get some idea of the rate of flow, but there is no doubt that at this place there is enough water to supply many times the needs of Ajmer. The distance and difference of altitude are the only objections to the use of this supply. I am under the impression that it is the best supply in the neighbourhood of Ajmer, but it is quite possible that a sufficient though less superabundant supply might be obtained more economically from some other spot

The most convenient solution would be, perhaps, to pump it up the gorge north-east of Amba, and then connect it by gravitation with the Foysagar system.

23. Still further down the Sagarmati Valley, towards Bhaonta, there are numerous wells with a large yield. I was shown one situated about a mile north-east by east of Bhaonta, and south by west of Amba. It is worked with six "charas," though its diameter is not much more than 6 feet. It was being tested at the time of my visit, but I do not know yet the result of the test. Evidently the yield is very great.

24. *Conclusions.*—The valley of the Sagarmati below Ajmer constitutes the area most likely to yield a considerable addition to the present water-supply of the city.

25. Attention should be specially devoted to the alluvial area commencing at Dorai. The sinking of wells in rock, as at Somalpore, is uncertain, and the yield relatively to the area of the well is small. The wells in the alluvium at Dorai should be tested and the river-bed in that neighbourhood experimented upon.

26. The levels of the gorge at Amba should be surveyed, with a view to the possibility of raising the supply from the river-bed opposite Masina, so as to connect it with the Foysagar system.

27. I should like to know the results of a test of the river-bed opposite Masina. But even without such a test, I have no hesitation in stating that it contains much more than is needed for Ajmer. I believe that there is some difficulty in obtaining sufficient water-supply

for the Cantonment at Nasirabad. If the cantonment were removed to Bhaonta the surpuls from the Ajmer scheme, or merely the Bhaonta wells would probably amply suffice. When all the tests have been completed the feasibility of this proposal might be taken into consideration.

Sarsuti Valley.

28. I entered the Sarsuti Valley at Galti. This village is situated at the foot of an extensive slope of blown sand. It is possible and probable that the rainfall is somewhat less in the Sarsuti than in the Sagarmati valley, but the prevalence of blown sand in the Sarsuti Valley can scarcely be connected with any marked difference of climatic conditions. The proximity of the desert of Western Rajputana no doubt accounts for its presence. It is brought by the westerly winds and is arrested by the steep ridges that separate the Sarsuti and Sagarmati valleys. These sand slopes must act as effective water-reservoirs, in a manner comparable to that of the talus slopes of Baluchistan already several times referred to. At Galti village, at an altitude appreciably greater than that of the Sarsuti plain, the water of a shallow well sunk in the sand is only at 6′-5″ below the the surface. It sinks in dry years but apparently does not dry up. The water is very pure.

29. Where I crossed the Sarsuti between Galti and Dongri, on the 9th April, there was water flowing in the river-bed. A slight efflorescence was noticed on the surface of the soil near this spot, showing that the soil must be slightly salt. Rock is seen at several places in the river-bed in this neighbourhood, and the thickness of alluvium must be irregular and insignificant. The place struck me as one favourable for a dam, which might not be directly useful, perhaps, in the Ajmer water-supply, but would contribute to raise the ground-water level, and might be made use of for irrigation. Probably other dams could be thrown across the river-bed at other points higher up its course.

30. At Dongri I was shown two wells sunk in rock, and situated at some height above the level of the river-bed. I have no accurate figures regarding their yield. One of them is said to irrigate 15½ "bighas." These wells might be tested, but it would be more promising to make experiments in the sand of the Galti side of the valley, rather than in the rock on the Dongri side. Moreover, Galti is much closer to Budha Pushkar. Below Dongri, the valley of the Sarsuti is occupied by alluvium, which appears to be of fair thickness, and ultimately merges into that of the Sagarmati.

31. Opposite Khera-Tilora, the bed of the Sarsuti did not show any water at the surface. The water level seems to be 4 or 5 feet below surface at present.

32. Further down the valley, at Choandia, near Pushkar, there are several wells which are situated at a higher level than the bed of the Sarsuti and appear to yield an abundant supply. Detailed observations

on one of these wells are given by the Executive Engineer. At depth of from 22 to 30 feet, the percolation is over 1,200 gallons an hour. The diameter is only 6½ feet, and the percolation not far from 40 gallons an hour per square foot. The well is sunk entirely through sandy soil, and it is improbable that it could represent the yield of a local spring such as those met with in fissured rocks. If, as seems probable, it merely taps a uniform sub-soil flow, a well in the same neighbourhood with a diameter of 34 feet might suffice for the needs of Ajmer, the yield of the one well tested being more than one-thirtieth of requirements of the city. There are not data sufficient to assert that volume of water thirty times that yielded by this particular well flows beneath Chaondia, but the deficiency, if any, could be made good from other neighbouring localities, or it would probably be sufficient to go direct to the bed of the Sarsuti.

33. It may be noticed that when testing this well on different occasions, the Executive Engineer, and the Railway officials started their tests when a depth of over 4 feet of water still remained in the well. The figures do not therefore represent the maximum possible yield. When the depth of water is reduced to less than 4 feet, a great deal of sand is carried in with it, and there is a risk of injuring the well by leaving it unsupported. The same trouble is more noticeable in dry years than in normal ones, the yield still remaining otherwise unaffected. The small diameter of the well accounts for these facts, which indicate a considerable pressure in a very porous and rather incoherent soil, when the water is lowered beyond a certain level. An increase of diameter, by distributing the percolation over a greater surface would obviate this difficulty (so long as the same amount of water is drawn out).

34. *Conclusion.*—There seems no doubt that the supply available from the Sarsuti is amply sufficient, though the available data are not quite so ample as in the case of the Sagarmati.

35. Experimental wells should be sunk at Galti, in or near the river-bed between Khera-Tilora and Basali, about Chaondia, and west of that village towards the river-bed.

36. I understand that the water level is lower than it used to be over a considerable area formerly planted with sugar-cane. The construction of a dam west of Chaondia across the river-bed might tend to restore the former conditions. This is not essential, however, with respect to the Ajmer Water-supply Scheme.

Budha Pushkar.

37. This natural lake indicates the existence of an abundant store of water in the surrounding sand hills, which probably accounts for its formation by interrupting the drainage. There is no visible outflow, though the fact that the water is sweet indicates that an outflow does exist under-ground, and consequently that the store is also replenished. A reservoir of this sort is probably very slowly affected. By fluctuations in

the annual rainfall it would probably remain unaffected by a period of drought for a fairly long period after the rainfall had again become normal, while, at the same time, a dry year will not affect it to the same extent as it would a more superficial reservoir. I do not know whether there are any accurate records of its fluctuations of level, nor whether any connection has been observed between these and the amounts pumped from the lake. If the available data are not sufficient to form any sound conclusion, it is best to leave the lake untouched as a valuable reserve in case of an exceptionally severe scarcity. I am of opinion that the visible capacity of the lake does not express the available amount of water, as this no doubt percolated from the surrounding sand hills.

38. There are similar basins surrounded by sand hills in the Nushki Desert of Baluchistan, in places where it does not rain for years at a time As they do not dry up and as they contain sweet water, there must be a constant flow representing percolation from the sand hills. Its only source can be occasional showers.

Madarpura Kiranipura.

39. I examined the Madarpura Valley on account of its being represented on the geological map as occupied by alluvium. The circumstances, however, are not encouraging. The valley is on a watershed, with a very small drainage area. The alluvium is shallow and is entirely traversed by the wells which extend to a considerable depth into the rock below.

40. I saw a well situated about the centre of the valley north of the road to Srinagar. It is dry. Another well near the eastern edge of the valley is 77 feet deep. It contained 21 feet of water when I saw it (April 7th). It is said to irrigate about 9 "bighas," which seems correct judging from the area of the fields which it commands.

Another well, south of the road, also contains water. It is also very deep. I was told that it yields a poor supply, which, however, needs confirming.

41. The physical situation of these wells does not seem promising, and it is not worth testing them so long as there are more urgent experiments to be made.

42 There are several large wells above the dam of the tank at Kiranipura. Two of these which I visited are respectively 82 and 86 feet deep. The first of these is worked throughout the day with four "charas." It is said to fill again during the night, the water level rising by 20 feet. These statements are worth verifying, for they seem to indicate a very large yield It might be found that these Kiranipura wells situated quite close to the city might supply an appreciable share of its needs: There would be probably a heavy compensation to pay, for the land irrigated seems very valuable. It is planted with roses and jasmine.

43. I was told that the 82 well used to become exhausted twice a day in 1900, instead of only once as at present. Even then the yield would seem very large. I unfortunately omitted to note its diameter. This is, perhaps not less than 16 feet in which case the statements made to me would indicate a percolation of not less than 2,400 gallons an hour, and 11 gallons for every square foot. The well should be systematically tested.

44. The 86 feet well is said to have become "insufficient" in 1900, 1902, and 1906. The exact meaning of this statement is uncertain.

45. In conclusion, it is evident that these Kiranipura wells should be carefully tested, and their behaviour during the past dry years ascertained as far as possible. When these data have been collected, it will become possible to consider whether they can enter in the improvement scheme.

Kair Tank.

46. With regard to Kair tank, the data available will scarcely suffice for drawing safe conclusions. We only have one test of one well below the dam, performed in March 1905. The condition of the tank at the time of the experiment is not stated, but the previous rainfall must have been fairly good, for the tank is said to have contained 13·55 million cubic feet in 1904, against only 7·75 in 1906. The infiltration at time of the experiment was about 2,500 gallons an hour. The diameter of the well is not stated. I did not measure it, but it is fairly large, I should say not less than 15 feet. This would give a percolation per square foot of area of about the same order as that of the wells at Kiranipura.

47. Fresh trials should be made this year in this well and other neighbouring ones after the Kair tank has dried up. The villagers told us that the wells dried up last year, but these statements are not very reliable. Any how, further data are needed before the case of the Kair tank can be seriously considered.

48. For improving the water-supply of Ajmer, there are two schemes which appear very suitable. One is to obtain water from the Sarsuti or its neighbourhood, near Galti or Chaondia, and pump it over the sand ridge at Galti so as to connect it with the Budha Pushkar system. The second scheme consists in sinking large shallow wells in the bed of the Sagarmati opposite Masina, and pump the water through the Amba gorge, to connect it with the Foysagar system. The latter scheme seems to promise the more abundant supply and necessitates pumping the supply only once, while in the case of the Sarsuti scheme the water has to be raised twice, first over the Galti ridge, and then over Pushkar one.

49. In connection with the Sarsuti scheme, tests should be commenced at the points that I have recommended when dealing with the Sarsuti Valley. In connection with the Sagarmati scheme, the tests will have to be made in the broad expanse of the river opposite Masina.

50. The Sagarmati should also be tested at Dorai, in case there is any economical advantage in drawing the supply from this spot rather than from Masina.

51. The capabilities of a well sunk in the bed of the Anasagar should be thoroughly tested after the lake has dried up in the present season.

52. It would be advisable to avoid using the water from Budha Pushkar so as to give the lake every chance of recovering itself. The complete efficiency of the Sagarmati or Sarsuti schemes will not be proved by actual practice so long as we do not get a year of severe drought. It is most unlikely that either of these schemes would fail even then. But in case of partial failure, then Budha Pushkar would remain to fall back upon, and then it would be thoroughly tested. I am inclined to think that even with the present scheme, Budha Pushkar constitutes a sufficient reserve. But this has never been ascertained, and it is too valuable a reserve to experiment upon so long as an alternate scheme is not in existence.

53. Kiranipura and Kair cannot be taken into consideration without further tests. Kiranipura would certainly imply heavy compensation. The Sagarmati and Sarsuti schemes should imply little or no compensation.

54. The Bisla tank improvement does not seem important enough to justify heavy expenditure.

55. I shall be on leave during the next three months, but if, in the meanwhile, the results of any of the tests recommended in this report should call for the necessity of further advice, I hope that the Director of the Geological Survey of India will be able to give the services of one of my colleagues for this purpose.

(Sd.) E. VRENDENBURG,
Geological Survey of India.

Ajmer, 11th April 1907.

APPENDIX VI.

Extract from Mr. A. E. Silk's Note on a Sanitary Survey of Ajmer, dated 11th May 1907.

In a note, dated the 3rd May 1906, the Sanitary Commissioner with the Government of India remarks as follows :—

"In my opinion a sanitary survey of Ajmer with schemes for the increase and improvement of the water-supply, for the efficient removal of night soil and sullage, and for the draining and paving of the city, should be prepared under the superintendence of an Engineer experienced in dealing with such schemes, The schemes could then be carried out gradually as funds become available. The alternative is the frittering away of large sums on measures of palliation involving a great waste of money and the continuance of nuisances which are offensive to the senses and dangerous to life."

At the instance of the Government of India I have been deputed by the Government of Bengal to undertake this survey, and it will probably be convenient if I treat the subject under the three heads mentioned by the Sanitary Commissioner. I arrived at Ajmer on the 2nd May 1907, and after a careful inspection of the town and surrounding country and a perusal of the papers relating to these subjects, I think I am now in position to offer some preliminary suggestions as to what should be done in the first instance to obtain the objects indicated by the Sanitary Commissioner. I am afraid that my suggestions, if approved, will take some time to carry out and will mean great delay before any real improvement in the sanitary condition of Ajmer can be effected, but after some years' experience in sanitary works, I have been forced to the conclusion that they are works that should not be undertaken without the most careful and searching preliminary enquiries. These are much more necessary in sanitary work in India than in any class of work I know of, for failures dishearten local bodies, whose incomes are not very large and whose borrowing capacities are correspondingly limited. From the last Annual Report of the Ajmer Municipality it would appear, however, that financially the town is much better off than many others; its debt is very small and its cash balance at the end of the year (1905-06) enormously, and in my opinion unnecessarily, large. I may state at once that I can hold out no hope of its being possible to effect any real improvements in the sanitary condition of Ajmer within the next two years at the very earliest, for everything, as will be seen hereafter, hinges on the efficiency of the water-supply. Cleanliness of one's own person is impossible without a plentiful supply of good water, and it is the same with towns; only, comparatively larger supplies of water are required on account of the great waste that goes on.

WATER-SUPPLY.

2. The sources of the water-supply appear to be many and various. The greatest quantity of water supplied to the town proper is obtained from the Foysagar, and at the present time the water is deficient in quantity and quality. From papers that have been placed before me it appears that this water has been consistently declared from chemical analysis to be unfit for potable purposes: in fact, in the Annual Report for 1897-98 it is recorded that "one sample from a road hydrant was

found to contain germs of enteric fever." Judging from the crowds of people gathered round the standposts, it would appear that the distribution system is faulty also: either the standposts are too few in number or the pipes are too small, and consequently the water does not issue from the standposts quickly enough. In all properly-designed systems it should be possible to draw off from each tap at least 6 gallons a minute. The other sources of supply are Colonel Dixon's Diggi, the Jhalra, the Katan Bao and numerous private wells. I inspected the Diggi, and am bound to say that I have seldom seen a more disgusting-looking water being used for potable purposes, and yet I was told that the people preferred this water to ordinary tap water. The Jhalra water appeared to be in great demand, and both it and the water of the Katan Bao were quite satisfactory as far as appearance goes. I think, however, that if samples of water from the various water-supplies were thoroughly examined bacteriologically both qualitatively and quantitatively, that is to say for the presence of the bacilli of the coli group per cubic centimetre, the results would not only be surprising but alarming, and I would suggest that enquiries be made as to whether the services of Professor Hankin of Agra could not be obtained to make these examinations on the spot. In this connection I would point out that it is a duty incumbent on every local body that undertakes the supply of drinking water to ascertain from time to time that the water that is being supplied is of a good potable quality and not dangerous to the health of the consumer.

3. From a casual study of the vital statistics as given in the Municipal Reports, it would appear that the inhabitants suffered but little ill-effect from drinking the dirty water I have described in the foregoing paragraph, and I must say that I was extremely surprised at this. The Civil Surgeon kindly supplied me with a statement of mortality in Ajmer for the past 30 years, and on examining this I find that the general death-rate was higher in 1906 than it had been for the previous 20 years, omitting the famine years of 1899 and 1900. The death-rates from the principal diseases in which impure water plays a part, during the previous 10 years, were as follows:—

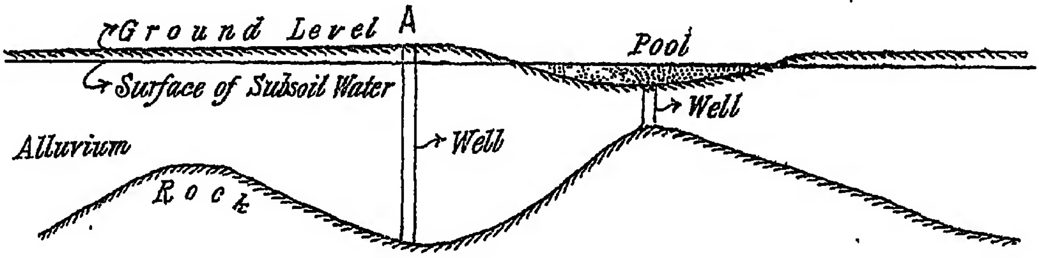
Cholera 0·16, fever 17·47 and bowel complaints 4·06. I am bound to say that it is an extraordinary thing that there are not more deaths from cholera, but probably the germs are unable to live through the excessively dry heat. It would appear that fever is accountable for the greatest number of deaths, and under this head is included of course enteric fever. I was informed by one or two residents that the number of cases of enteric fever was certainly increasing, but then the germs of this disease can be conveyed through milk as well as water. The death-rate among children under five years of age was in 1906, 46·68 per cent. of the total mortality, and it is quite possible that enteric fever was responsible for most of the deaths.

In 1906 the death-rate from fevers was 26·03, or 50 per cent. above the average of the previous 10 years, while that from bowel complaints was 38 per cent. above. These figures must, I think, be viewed with

alarm, and I would most earnestly urge the Municipal Committee to have a complete bacteriological survey of every source of drinking water supply made. There can be but little doubt that the death-rate in Ajmer is increasing instead of decreasing, and an ample supply of good wholesome drinking water will go far to produce a normal state of affairs.

4. A few weeks previous to my visit, Mr. E. Vrendenburg of the Geological Survey of India had made a thorough examination of the other possible sources of water-supply for Ajmer, and it was a great advantage to me to have his note placed in my hands on my arrival here. It is perfectly clear from this note that a grave mistake has been made in the past in attempting to store water above ground on a very pervious sub-soil and in a climate where evaporation is very rapid, instead of tapping the great underground rivers of sub-soil water travelling down the alluvial valleys over impervious rock. Mr. Vrendenburg has recorded that "The valley of the Sagarmati below Ajmer constitutes the area most likely to yield a considerable addition to the present water-supply of the city" (*vide* paragraph 24), and further: "There seems no doubt that the supply available from the Sarsuti is amply sufficient, though the available data are not quite so complete as in the case of the Sagarmati" (*vide* paragraph 34). Mr. Vrendenburg finally states in paragraph 48 that wells sunk opposite Masina, or perhaps Dorai, in the Sagarmati Valley would appear to be capable of giving a suitable supply. *Prima facie* it would seem that a new and complete water-supply scheme would be a very simple matter, and that it only means the sinking of wells or building of collecting galleries in the beds of the rivers, the setting-up of pumping plant and the laying of a few miles of pipe, and the whole question would be satisfactorily settled once and for all. As I shall show in the succeeding paragraphs, the matter is not so simple as it seems, and very much more work must be done and information collected before it will be possible even to set about getting out the necessary designs and estimates.

5. It is a well-known fact that the bed of the ocean is just as rugged and mountainous as the surface of the dry land, similarly the beds of valleys in rocky tracts are as uneven as the hills that border on them. The process going on in nature is the denudation of the hills and the filling-up of the valley with the wash-down or alluvium therefrom, and there can be no doubt that the sides of the hills and spurs therefrom slope down under the alluvium in the valleys. If then a longitudinal section of the deepest part of a valley in hilly country were made, it would be found to be something like this:—



The sub-soil water is constantly moving towards a lower level, and for this to take place the surface must be on the slope. The ground is not at an uniform level, and where it falls below the level of the sub-soil water a pool or lake is formed as shown in the sketch. Now suppose a well were sunk in this pool and it so happened that rocks were found very near the surface (shallow well), and heavy pumping was commenced, the level of the sub-soil water would be reduced after a time, and in a year of scanty rainfall it might be reduced down to the level of the rock at the bottom of the well, and the well would be said to have run dry. If, however, a deep well were sunk at the point A, it would not run dry until the whole of the sub-soil water stored on the basin between the two ridges of rock have been pumped out. Before, therefore, the sites of the wells in the Sagarmati or Sarsuti valleys can be decided, it will, I think, be admitted that it is most necessary to have a longitudinal section of the rocky bed of the valley made two or three miles at least above and below the points indicated in Mr. Vredenburg's report. This can be done either by means of wells or possibly at less cost and more quickly by boring. The best procedure to follow probably will be to decide on the sites of the wells or bore-holes and fix bench marks at each of them; the reduced levels of the rock and the sub-soil water underneath can then be easily ascertained by simple measurements as the bore-holes or wells are completed. Where the rock is deepest below the surface, a transverse or cross-section of the valley should also be made, so that some idea may be obtained of the extent of the depression in the rock-bed, from which it will be possible to arrive at some conclusion as to the quantity of sub-soil shown in the basin. Unless and until this information is obtained it will be quite impossible to say what design of pumps would have to be adopted, for where the water does not fall below 20 feet below ground level the pumps can be kept at that level, but if this depth is exceeded the pumps must be correspondingly lowered.

6. As soon as the best site for the pumping station has been decided on, from the information obtained as recommended in the preceding paragraph, it will be necessary to sink a trial well and pump from it continuously for at least six weeks at the driest time of the year, in order to ascertain the best size of well and the number to give the daily supply required for the town. In this connection I would state that I have handed over to the Executive Engineer a copy of a report on a similar experiment that was carried out under my direction on a well sunk in an old bed of the river Sone in Bengal, and I would suggest that the experiment for Ajmer be carried out on similar lines, although it is quite possible that the local officers can improve on the methods. For instance meters are available here, I believe, and so the yield might be more accurately measured through them, instead of over a notch.

7. It will be convenient at this stage to discuss the question of the quantity of the daily supply, and it will perhaps clear the way if I state at once that I would recommend that the whole of the drinking water-supply be obtained either from the Sagarmati or Sarsuti Valleys and the

Foysagar water be used only for conservancy and manufacturing purposes and for watering gardens. I am aware that this means an absolutely new drinking water-supply, but the existing pipes would appear to be in need of considerable re-modelling if an efficient distribution system is to be maintained in Ajmer. In years of short storage in the Foysagar the supplies to gardens should be first cut off; this no doubt will be considered rather a hardship by owners of gardens, but gardens are a luxury, not a necessity. If the shortage was excessive, the connection for manufacturing purposes would have to be cut off, but the Railway Workshops is the only connection that takes any large quantity under this head, and the Railway Administration would still have the Budha Pushkar tank to fall back on. This tank certainly shows signs of drying up, but it has, I understand, been rather heavily drawn upon during the recent dry years, and it is possible that it might fill up again to its original level in years of normal rainfall. During the year 1905-06, the total consumption of water is stated in the Annual Report to have been 241,610,000 gallons, but of this quantity 58,110,000 gallons were used in the Railway Workshops. If this latter quantity is deducted, the daily average quantity was just about 7 gallons per head, but this supply was obtained from the Foysagar alone, and, as has been shown above, large quantities of water are obtained from other sources. There are 87 private connections, of which 6 took over 1,000,000 gallons during the year 1905-06. These are such excessive consumptions for private consumers that I think they should be left out of any calculations for attempting to arrive at the probable consumption for domestic purposes, but even by omitting these I find that the average daily consumption of the other 81 private connections was 1,000 gallons. It is perfectly clear to my mind that the Municipal water is being used for other than purely domestic purposes. This may be all very well when water is obtained fairly cheaply as by gravitation; but if the water has to be obtained by pumping from works costing a considerable sum of money, some control must be exercised over the purposes for which it is used. If it is assumed that one-half the total quantity used by private connections during the year 1905-06 was for domestic purposes, while the other was used for gardens, we shall find that the quantity of water supplied to the whole population was only about 5 gallons per head. In an extremely hot and dry climate like that of Ajmer, this is an altogether inadequate supply, and in my opinion any new scheme should provide for at least 10 gallons per head, and if funds are available, for 15 gallons. Until an ample supply of good drinking water is supplied, it will be useless to think of trying to close up the other dangerous sources of water-supply, for I regard all tanks or wells whence water is obtained by the indiscriminate dipping of private vessels and *mussucks* as open to the gravest objections.

8. To sum up my recommendations in the matter of water-supply, they are as follows: —

(*a*) After the most careful and searching preliminary enquiries to obtain a supply of water for domestic purposes only from wells sunk either in the Sagarmati or Sarsuti valleys.

(*b*) The daily supply to be on a basis of 10 and if possible 15 gallons per head to be raised from the wells by continuous pumping throughout the 24 hours, a sufficient reserve of pumping machinery being provided to allow for necessary stoppages for repairs, allowance to be made for increase in population in next 30 years.

(*c*) The rising main to be of sufficient capacity to deliver the whole daily supply in 24 hours.

(*d*) A service reservoir to be erected in some suitable spot to be decided hereafter, of sufficient capacity to meet the periods of maximum demand from the distribution system.

(*e*) A distribution system of sufficient capacity to deliver the whole daily supply in 6 hours, care being taken that the main pipes pass through the highest parts of the town before they descend to the lower parts.

The valley of the Sagarmati as far as Masina is much larger in area than that of the Sarsuti as far as Chaondia, and a larger supply of water should therefore be obtainable from the former, and if the enquiries that I have recommended above show that a very ample supply is available in the Sagarmati, then it would be possible to supply water to Nasirabad, and thus save all the expense of the removal of the Cantonments, which I understand is under contemplation.

* * * *

AJMER,

The 11th May 1907.

(Sd.) A. E. SILK,

Sanitary Engineer, Bengal.

APPENDIX VII.

Extract from Mr. A. E. Silk's Note on the Ajmer Water-supply Scheme, dated 11th January 1908.

In paragraphs 4 to 6 of my Sanitary Survey of Ajmer, dated the 11th May 1907, I explained why it was necessary that we should know something of the levels of the rock underlying the valleys of the Sagarmati and Sarsuti Valleys before the site of the experimental pumping well could be decided. So far only the valley of the Sagarmati has been explored in the manner I wished, and I venture to think that the information that has been obtained in this valley fully bears out the opinion expressed by me in paragraph 5 of my Sanitary Survey. The borings were commenced opposite Dumara, and carried on to below Masina, at both of which places, there are spurs running out from the hills, and the longitudinal section attached hereto shows how greatly the depth of the rock-bed below the surface of the valley varies. At Masina a cross-section of the valley was made which shows that there is, as it were, a narrow subterranean gorge, and there can be no doubt that a large quantity of sub-soil water must pass through it.

2. I have recently carefully examined the Sagarmati Valley between Dumara and Masina, and I am of opinion that the time has now come when a trial well should be sunk in this valley, and I would advise that it be sunk somewhere in the neighbourhood of Pits Nos. 37 and 38. The well should be 6 feet in diameter and should be built of solid masonry throughout, so that water can enter it through the bottom only. The bottom of the well should be kept about 10 feet above the rock-bed, so that the sub-soil water can have free access to the well. Several kutcha observation wells will be required in order to ascertain the effect of the pumping from the central well on the water level in the surrounding tract Detailed instuctions as to how the whole experiment is to be carried on, will be issued separately to the Municipal Engineer. In addition to the above, I think it would be advisable to take two more cross-sections of the Sagarmati Valley at Pits Nos. 18 and 24.

3. It must be distinctly understood that the object of an experimental well of the character described in the preceding paragraph is to ascertain only the *number and sizes of the wells that will eventually be required to give the full daily supply of water*. I think it will be quite obvious that it would be quite impossible to ascertain by any experiment whether the ground in which the wells are sunk will continue to give the full daily supply of water over a year or series of years. No direct information on this point is obtainable, and so we must have resort to referential methods based on reasonable assumptions. In hilly countries with comparatively narrow valleys it is fairly easy to arrive at a rough estimate of the water capacity of the sub-soil in which wells are sunk. The only source of the water is rain, and it is quite possible to ascertain

without much error the area on which the rain falls. An inch of rain falling on an area of one square mile means that 14½ million gallons of water have to be accounted for. If this quantity fell into an impervious tank on which there was no draft it would gradually disappear by evaporation only Under natural conditions, however, rain falls on ground of various consistencies, *e.g.*, rock, clay, sand, etc., and it depends on the nature of the ground whether the rain water simply flows off on the surface in the form of rivers or whether it soaks into the ground and forms an underground river or whether it does both. In the case of the country round Ajmer, the last-mentioned condition undoubtedly prevails, and owing to the sandy nature of the ground in the valleys a large quantity of water is absorbed and forms an underground river. It is this underground river that we desire to obtain information about and form a rough estimate of its volume. The catchment area of the Sagarmati up as far as Masina has been ascertained to be 90 square miles, and if an inch of rain fell on this area, and was absorbed into the ground, a volume of 1,300 million gallons would flow underground past Masina during the year. From the rainfall records of the past 24 years it is found that the annual rainfall at Ajmer has only been less than 10 inches on two occasions, *viz.*, 1891 and 1905, and in these years very little water was impounded in the Foysagar and Anasagar and other tanks in the Sagarmati Valley. This is easily understood when it is borne in mind that water will not flow over pervious ground until that ground becomes itself saturated, or unless the rainfall is very heavy and the slope of the ground very steep. In most years, however, the rainfall is considerably more than 10 inches, and it will thus be seen that if we assume that only one inch of the rainfall in each year is absorbed into the ground or less than 10 per cent., there will be considerably more water available in wells at Masina than will ever be required for the supply of Ajmer.

4. So far I have only considered the Sagarmati Valley, and had my advice been followed to have both the Sagarmati and Sarsuti valleys sounded, I should have been in a position to decide finally from which valley the supply of water for Ajmer should be obtained. During June and July three borings were sunk near the villages of Galti and Vasali, but these borings are at one side of the valley instead of at the lowest part of it, and they are consequently of little value in helping me to form an opinion as to the possible position of a pumping station for the supply of water to Ajmer. These bore holes were found to be artesian in character; but, as pointed out by me in a demi-official letter, dated the 17th September 1907, to the Commissioner, these conditions could not continue when there was such a heavy draft as 700,000 or 1,000,000 gallons per day, year in and year out, as the catchment area must be so small. This opinion has, I understand, been confirmed by Mr. Vredenburg, of the Geological Survey of India. In another demi-official letter, dated the 19th November 1907, to the Commissioner, I stated that I did not consider any further borings in the Sarsuti Valley necessary, but I find that its catchment area as far as Nand is some 51

square miles, and that being so I have no doubt that wells sunk in this valley should also give an ample supply of water to Ajmer. Now that boring tools are available and we have at hand workmen experienced in making borings, I think the opportunity should not be lost of having this valley surveyed in the same manner as that of the Sagarmati. The information obtained from such a survey will enable me to compare the merits of the two possible sources of water-supply for Ajmer, and to form a definite opinion as to which source of supply should be resorted to.

* * * *

AJMER,
The 11th January 1908.

(Sd.) A. E. SILK,
Sanitary Engineer, Bengal.

APPENDIX VIII.

Mr. Heinmann's Report on Well Test in the Sagarmati Valley, 1908.

General.

The Sagarmati River has its source in the hills surrounding Ajmer and receive the drainage of the whole area.

About 9 miles from Ajmer in a south-westerly direction the river passes round the hill spur on which the village of Dumara stands, and flows through a wide sandy valley with steep hills on each side towards the village of Bhaonta.

This valley is most fertile, and was selected by Mr. Silk, Sanitary Engineer, Bengal, as the most probable place from which an adequate supply of water could be obtained for Ajmer.

Borings.

Borings were made along the river bed from Dumara to Mesidhia, to ascertain the strata and the levels of the rock-bed of the valley with cross-sections.

The longitudinal section of the valley so obtained showed a more or less even slope of rock-bed in the direction of the flow of the river until a point nearly opposite the village of Mesidhia. At this point the rock rises abruptly and forms a natural underground dam, which holds up much of the sub-soil water.

The catchment area of this river to the site of the proposed wells is just 100 square miles.

The first cross line was from Pit No. 16 in a north-westerly direction to the well of Bhagwan Singh and thence in a north-easterly direction towards Amba Dhani. From this was obtained the general lie of the rock across the valley.

There is a ridge of rock between bore holes Nos. 10 and 13 which themselves show the lowest rock levels on the cross-section.

It is seen that these depressions occur just below the bed of the two nullahs which unite with the main stream near bore hole No. 34. It is therefore probable that these depressions are the original nullah beds.

The second section line was taken between bore holes No. 34 and 8 and shows the rock level at its lowest part. (The ridge of the rock continues across the valley west of this cross-section line).

The even level of the water in this cross-section also shows that the section has been taken at right angles to flow of the sub-soil water.

With this data before him Mr. Silk decided that the most advantageous place to sink a trial well would be somewhere on this line in the neighbourhood of bore holes Nos. 36 and 37.

Site of trial well.

The site actually selected was at bore hole No. 37, this being close besides the Ajmer-Bhaonta Road, which made it easier to carry away the water pumped from the trial well.

The trial well.

The trial well was made six feet diameter of pucca masonry and plastered, so as to prevent any water entering except through the bottom. It was intended to sink the well to a depth of 32 feet or 10 feet above the rock level, but owing to the tremendous inflow of water it was not possible to sink it more than 26 feet with the appliances available.

From a previous test on the well of Bhagwan Singh (one of the best wells in the valley), it was found that the maximum rate of inflow was 75 gallons per square foot per hour. It was therefore taken that the maximum amount of water to be dealt with in the sinking of the well would be :—

64 square feet (*i.e.*, area of excavation) multiplied by 75 or 4,800 gallons per hour. Instead of this a discharge of over 15,000 gallons per hour has been found at a depth of only 18 feet.

A large Worthington pump was taken out from Ajmer and a boiler from Budha Pushkar with much trouble, owing to there being no proper road after the 8th mile from Ajmer.

The boiler, however, had not sufficient capacity to allow the Worthington pump to work at full capacity, and it was found that about 7,000 gallons per hour was all that could be obtained from this combination.

The failure to get the well down to the pre-arranged level, however, in no way affects the results of the test.

The tests were carried out in accordance with instructions received from Mr. Silk, and were made to ascertain the *maximum steady discharge* that could be obtained from the well. The test also shows the effect on the water level in wells in the neighbourhood resulting from constant pumping on the test well.

The tests.

The test was carried out in the following manner :—

Each day the water surface in the test well was lowered to a pre-arranged level, and by regulating the pumps maintained at that level, for about 10 consecutive hours. The water discharged from the well was received in a collecting chamber, from which it was allowed to flow in an even stream into a gauge chamber discharging over a triangular notch weir by which the discharge was measured. From the down stream side of the weir the water was conveyed in pipes to a distance from the test well, so that none of the water taken from the well should soak back into it.

Method of testing.

The discharge was read every hour, and the water level in the test well recorded at the same time and averages deduced for each day.

The water level in the observation wells and cultivators' wells in the neighbourhood was noted each day before pumping commenced and when pumping had proceeded for about 5 hours.

At the close of each day's test the time the water in the test well took to rise each 6 inches, was noted.

[TABLE.

The following are the tabulated results of the Tests :—

TABLE I.—*Statement of Daily Average Discharge.*

Date.	Average head on well.	No. of hours average head was maintained.	Average daily discharge galls. per hour.	Average head in round numbers.	Average discharge in galls. per hour.	Remarks.
27-5-08	1·5	10	2,645			
28-5-08	1·5	10	2,645	1·5	2,599	
29-5-08	1·5	10	2,506			
1-6-08	2	10	3,848			
2-6-08	2	10	3,990	2·0	3,895	
3-6-08	2	10	3,848			
4-6-08	2·5	10	5,080			
5-6-08	2·5	10	4,900	2·5	4,889	
6-6-08	2·5	10	4,752			
7-6-08	2·5	10	4,826			
8-6-08	3	10	5,590			
9-6-08	3	10	5,680	3·0	5,659	
10-6-08	3	10	5,590			
11-6-08	3	10	5,775			
12-6-08	3·5	2*	6,138			* The foot valve of the Worthington pump had to be repaired, and pumps could not work full time in consequence.
13-6-08	3·5	8	6,138	3·5	6,138	
14-6-08	3·5	10	6,138			
15-6-08	3·5	9	6,138			
16-6-08	4·0	5	8,300			
17-6-08	No pumping on this date, as steam could not be kept up to supply the Worthington pump. After instructions and personal trials by undersigned the work was continued satisfactorily on 18th.					

TABLE I.—*Continued.*

Date.	Average head on well.	No. of hours average head was maintained.	Average daily discharge galls. per hour.	Average head in round numbers.	Average discharge in galls. per hour.	Remarks.
18-6-08	4	9	7,970	4	7,997	During this time I was trying to arrange for more power, but could not get any until 24th.
19-6-08	4	9	7,970			
20-6-08	4	7	7,860			
21-6-08	4	8	7,970			
22-6-08	4	9	7,970			
23-6-08	4	10	7,970			
24-6-08	4	10	7,970			
25-6-08	4·5	8	9,280	4·5	9,367	
26-6-08	4·5	10	9,455			
27-6-08	5	5	10,600	5	10,600	
28-6-08	5	9	10,600			
29-6-08	5·5	10	11,130	5·5	11,821	The bottom began to blow slightly.
30-6-08	5·5	10	12,513			
1-7-08	6	10	13,243	6·0	13,243	
2-7-08	6	10	13,243			
3-7-08	6·5	10	14,462	6·5	14,307	
4-7-08	6·5	10	14,152			
5-7-08	7·0	3	15,258	7·0	15,582	Heavy rain, testing stopped.
6-7-08	7·0	1	15,918			
7-7-08	7·0	10	15,588			

TABLE II.—*Rate of Replenishment.*

6" depths rising from lowest level.	Time in minutes.											
	Head. 1·5	Head. 2·0	Head. 2·5	Head. 3·0	Head. 5·5	Head. 4 0	Head. 4·5	Head. 5·0	Head. 5·5	Head. 6·0	Head. 6·5	Head. 7·0
Top 6 inches.	Not recorded.	54	63	129	170	181	190	240	Whole night.	...	...	...
2nd		9	10	14	22	35	67	63	105	134	179	213
3rd		3	3	3	4	3½	5	4¼	6	12	23	27
4th	...	2	2	2	3	1⅞	2	2	2	3¼	3¾	4¼
5th	...	...	1	1⅓	1½	1¼	1½	1½	1½	2	2	2
6th	...	...	...	½	1	1	1	1	1¼	1	1¼	1½
7th	...	...	...	...	¼	1	1	1	¾	1	1	1
8th	...	...	...	...	...	⅓	¾	¾	¾	⅞	⅞	1
9th	...	...	...	...	...	...	½	½	½	½	¾	1
10th	...	...	...	...	...	...	...	½	½	½	½	1
11th	...	...	...	...	...	...	...	...	¼	½	½	½
12th	...	...	...	...	...	...	...	...	...	¼	½	½
13th	...	...	...	...	...	...	...	...	...	...	¼	⅓
14th		...	...	...	...	...	...	...	...	...	...	½

Maximum rates of inflow deduced from above table.

Head.	Quantity gallons per hour.
2	2,653
2·5	5,306
3·0	10,612
3·5	21,224
4·0	15,918
4·5	10,612
5·0	10,612
5 5	21,224
6·0	21,224
6·5	21,224
7·0	15,918

TABLE III.—*Level of water in Observation Wells.*

See ferrotype attached.

RESULTS OF TESTS.

Table 1.

From this table it appears that from a well of 6 feet diameter 10,000 gallons, per hour can be pumped without fear of the bottom of the well being disturbed by the influx of water. That is, that maximum safe head for continuous pumping is 5 feet.

Table 2

cannot be depended on to such a degree, as after 2 5 feet of head was put on the well the inflow was so rapid that the time had to be taken in fractions of a minute, and on the quickness of the observer the results depend. An error of a quarter of a minute, which quite easily can creep in, makes a difference of about 10,000 gallons when the reading is between $\frac{1}{4}$ and $\frac{1}{2}$ a minute. This table is therefore of little use except to prove the rapid flow of the sub-soil water.

Table 3

which shows the effect of pumping on the sub-soil water levels is most important. Taking first the trial well itself from the table it will be seen that on May 27th at the beginning of the test, the water level stood at the reduced level of 7·64 and sank to its lowest level 6·97 on the 19th June. That is to say, after 21 days' pumping, during which time 900,000 gallons of water were pumped, the water-level in the well was only reduced 0·67 feet or 8 inches.

The effect of pumping on the observation wells is also shown by Table 3.

The nearest well is a cultivator's well No. 12 in the table and is 70 feet from it only. On the 1st day's pumping with 1·5 feet head this well sank 1·08 feet; with 5 feet head it only sank 0·94, which shows that the slope of the sub-soil water at this head is very steep. With a 7 feet head it sank even less 0·92.

Next taking the 4 observation wells 200 feet from the well, that is Nos. 1, 2, 3, 4, the original reduced levels of the water were :—

No. 1	7·11
No. 2	7·54
No. 3	7·77
No. 4	7·56

The falls due to pumping were with—

Well.	Head.		
	1·5	5·0	7·0
No. 1	0·08	0·08	0·13
No. 2	0·08	0·09	0·21
No. 3	3·13	0·08	0·25
No. 4	0·21	Water rose owing to rain.	0·17

These figures show that pumping at the test well had very slight effect on these wells 200 feet away.

The reduction in water level in them from the 27th May to June 19th was :—

No. 1	0·92	=	11 Inches.
No. 2	0·92	=	11 ,,
No. 3	0·88	=	10½ ,,
No. 4	0·88	=	10½ ,,

The next well is No. 5—550 feet from the test well.

The effect of pumping on this well was :—

Well.	Head.		
	1·5	5·0	7·0
No. 5 ...	0·04	0·08	0·16

Finally taking the following wells :—

	1·5	5·0	7·0
No. 6	0·00	0·00	0·04
No. 7	0·00	0·08	0·08
No. 8	0·00	0·00	0·13
No. 9	0·08	0·00	0·04
No. 10	0·16	0·00	0·08

The total fall in the water between the 27th May and June 19th was :—

No. 6 ...0·34 = 4"

" 7 ...0·32 = 4"

" 8 ... *Nil* ...
" 9 ... *Rose* ...
" 10... *Nil* ...

} These wells were flooded by the recent rain, but were unaffected by the pumping before the rainfall.

From this it appears that only the two wells on the down stream side of the test well have been affected by the pumping, and actually while pumping was in progress up to a head of over 5 feet the depression of the water round the test well did not extend to this range of wells, the nearest, No. 7, being 700 feet from the test well.

Taking all these figures into consideration it appears that the supply is plentiful and the slope of the sub-soil water during pumping steep.

From these results the question of the number and size of wells required will be worked out, and the complete scheme will shortly be ready for final discussion.

These tests have been most satisfactory, and from the result it appears that a splendid supply of water is at last available for Ajmer.

A copy of the Chemical Analysis of the water is given below.

Two samples were sent for analysis, one taken directly from the well and one from the discharge of the pump.

No.	Copy of label on bottle.	Total solids grains per gallon.	Chlorine grains per gallon.	Total hardness grains per gallon.	Fixed hardness grains per gallon.	Free ammonia parts per million.	Albuminoid ammonia parts per million.	Nitrites.
1	Water from well.	49	7·5	11·5	5·5	0·04	0·04	*Nil*
2	Water pumped from well.	48	7·2	11·5	5·5	0·01	0·03	*Nil*

Both of the above water samples are fit for potable purposes.

(Sd.) S. O. HEINEMANN,
Municipal Engineer, Ajmer.

APPENDIX IX.

Copy of a D. O. Letter, dated 23rd July 1908, from A. E. Silk, Esq., Sanitary Engineer, Bengal, to S. O. Heinemann, Esq., Municipal Engineer, Ajmer.

I have now had an opportunity of studying your report on the pumping experiment in the Sagarmati Valley, and I must express my great satisfaction at the careful and intelligent manner in which you have carried out the experiment and at the lucid report you have drawn up. There is just one minor detail that I think might be improved on and that, is, that you should have drawn out an enlarged plan showing the pumping well and the surrounding observation wells, as it is rather difficult to fully appreciate the results without seeing more clearly the relative positions of the wells.

I do not think it would be wise to take a working head of 5 feet, because unless the pumps are very carefully and steadily worked, the head will vary, and it appears that the bottom of the well begins to blow up with a head of 5·5. The wells themselves will be a very small item in the total cost of the scheme. I would therefore recommend that you take the working head to be 2 feet only, and if the pumps are kept going continuously throughout the 24 hours, as I think they should be, you will require three wells of 14' diameter to give you a daily supply of 15,500,000. The wells should be 200 feet apart with their tops above flood level. The suction pipe should be laid at the level of the tops of the wells with the necessary intermediate supports. With this arrangement if a well sinks it will not carry the pipe with it. The suction pipe should be of steel. Allow Rs. 1,000 for electric gauges for the wells.

You ought not to have any trouble sinking the wells if you use proper dredgers, for with these you need not pump out any water.

APPENDIX X.

Rainfall and Storage of the Foysagar Lake.

Year.	Rainfall in Inches.	Quantity stored in m. c. ft.	Remarks.
1892	20·87 ...	98·46 ...	
1893	32·83 ...	107·43 ...	
1894	26·99 ...	9·96 ...	
1895	24·43 ...	88·75 ...	
1896	26·44 ...	78·06 ...	
1897	23·29 ...	99·50 ...	
1898	12·97 ...	28·65 ...	
1899	10·10 ...	11·71 ...	
1900	25·64 ...	150·00 ...	
1901	13·57 ...	13·13 ...	
1902	17·04 ...	44·81 ...	
1903	18·28 ...	115·20 ...	
1904	16·80 ...	73·87 ...	
1905	7·11 ...	45·71 ...	
1906	24·23 ...	90·92 ...	
1907	26·17 ...	150·00 ...	

APPENDIX XI.

Note by Sir Swinton Jacob, dated 12th April 1910, on the Proposed Scheme for Augmenting the Water-supply of Ajmer from the Sagarmati Valley.

1. The Municipal Committee of Ajmer, at a meeting held on the 24th January 1910, at Ajmer, asked "that Sir Swinton Jacob of Jaipur be invited to inspect and report on the practicability of the new water scheme, with reference to its capacity to yield a sufficient quantity of water for the needs of Ajmer during years of scanty rainfall."

My remarks are therefore confined mainly to this phase of the question.

2. The proposed scheme is to sink a series of wells in the Sagarmati, about 9 miles from Ajmer; to raise the water by pumps and force it through a rising main into a storage reservoir, from which it would be distributed in pipes.

3. The total height to be pumped is 330 ft., omitting the extra head required to overcome friction.

The number of men employed in Railway Workshops 25 years ago was 3,000; it is now 7,700.

The city and the R.-M. Railway is said now to require about 850,000 gallons daily; of which the R.-M. Railway Workshops use 250,000 or about $\frac{5}{17}$ of this quantity. The suburbs are not yet supplied. The consumption will naturally increase, and in 1941 it is estimated it will be about 1,600,000 gallons daily.

The cost of the scheme is estimated to be about 10½ lakhs.

The maintenance charges, stated by Mr. Silk, the Sanitary Engineer, Bengal, will not exceed 0 75 annas per 1,000 gallons.

I am doubtful of this. Compared with other places it seems to me very low.

4. On the 5th April Sir Swinton Jacob, with Mr. Waddington (the Chairman of the Municipality) and Mr. Sanders (the Executive Engineer, Ajmer Provincial Division), visited the site selected for the trial well at Masina, and inspected the valley of the Sagarmati.

5. Mr. Vrendenburg, the Geologist, is of opinion, in his letter, dated 11th April 1907, that "at this place there is enough water to supply many times the need of Ajmer," and he considers that "the distance and the difference in altitude are the only objections to the use of this supply." He says further that "the complete efficiency of the Sagarmati or Sarsuti

scheme will not be proved by actual practice, so long as we do not get a year of severe drought. It is most unlikely (he adds) that either of these schemes would fail even then." It will be observed that even in his opinion, it is not a certainty.

6. Mr. Silk, the Sanitary Engineer, Bengal, in his letter, dated 11th January 1908, says: "The catchment area of the Sagarmati up as far as Masina has been ascertained to be 90 square miles, and if an inch only of the rain which fell on this area was absorbed into the ground, a volume of 1,300 million gallons would flow underground past Masina during the year," and he concludes from this "that there will be more water available in wells at Masina than will ever be required for the supply of Ajmer."

What guarantee is there that even if $\frac{1}{10}$ of the rainfall is absorbed in the ground that it will all reach the well area, and not find its way by gaps or fissures in the subterranean rocks, to a lower level?

7. He adds: "It will be quite obvious that it would be quite impossible to ascertain by any experiment whether the ground in which the wells are sunk will continue to give the full daily supply of water over a year or series of years. No direct information on this point is obtainable, and so we must have resort to inferential methods based on reasonable assumptions."

And in his letter dated 29th September 1908 he says: "In my opinion the results obtained show clearly that there is ample water in the Sagarmati Valley for supplying Ajmer.

8. Mr. Heinemann says: "Even during the worst famines it is said the wells in the Sagarmati Valley have never failed." This may be quite true, but it is not stated how much water was drawn. It is possible it might be different if powerful steam pumps were employed continuously.

9. The trial well 6 ft. diameter was tested from 27th May 1908 till the 7th July—the hottest time of the year—and the yield is stated to have been 3,895 gallons per hour, or 13,777 gallons per sq. ft. per hour, with a 2 ft. head. The object was to ascertain the maximum steady discharge that could be obtained from the wells. From this it is assumed that three wells each 14 feet diameter will yield at the same ratio, or 1,726,125 gallons a day.

It may be so, but is it safe to assume that it will be? Moreover, what proof is there that with such a constant demand, the yield obtained from a 6 feet well, for 40 days or so, will be constant and continuous for any length of time in this or in other wells?

10. It must be remembered we are dealing with underground areas and water-bearing strata of which little can be seen, and little known, excepting by actual trials, which should be made under circumstances truly representing the conditions required.

It seems impossible to make such trials, *i.e.*, such tests as shall fully satisfy all the conditions. The test ought to be more severe even than what will actually be required, so as to have a good margin for safety.

11. The water level of Ajmer is stated to have been only 7 to 10 feet below rail-level, 25 years ago;—now it is said to be 30 to 40 feet. There may be reasons to account for this, such as the draining of the Bisla Tank, the years of drought, etc., but in a country where the rainfall is known to be so precarious, and so partial, and so irregularly distributed, who will guarantee that such differences may not occur again? The Gazetteer remarks: "It only needs a long enough drought to dry up every well in Ajmer-Merwara."

Take for instance Budha Pushkar Tank. Before it was drawn upon the supply was believed to be inexhaustible, but we are now told that "this tank certainly shows signs of drying up,—it has been rather heavily drawn upon during recent dry years."

12. It is true that suggestions are made by which the supply of water might be increased, should the need arise, by building a concrete wall along the subterranean ridge of rock which appears to stretch across the valley below Masina, and by bunding up some of the nullahs above, so as to allow the rainfall to soak into the ground above. Both these suggestions are good; but unless the concrete wall filled up every deep crevice in the ridge it would be of little use,—and any water impounded, which soaked into the soil above, might do good, but the water might also possibly pass outside the influence of the pumping wells. The costs, moreover, of any scheme of this sort are not stated.

13. Taking all these points into consideration, although there is great probability that the Sagarmati Valley will yield a sufficient quantity of water for the anticipated needs of Ajmer, during years of scanty rainfall, I do not consider that the tests have been sufficient to prove it.

14. There is another point, however, which I think deserves consideration.

Mr. Goodwin, the Loco. Superintendent, R.-M. Ry., in his letter, dated Ajmer 1st February 1907, says: "Constant shortage of water appears to be a permanent thing, and seems to indicate that Ajmer is not a suitable place for workshops of such a size as that to which the R.-M. Ry. shops have attained."

Water is absolutely necessary to run trains through, and the stoppage of trains would mean starvation to a large number of people.

He also says: "No source of a sure and sufficient supply from which even the workshops demands could be met, exists within a distance from which it could be pumped," this, though, was written before the proposals regarding the Sagarmati were known.

A good supply of good water is absolutely necessary for the maintenance of the Railway service. It is in fact a matter of vital importance to the Railway.

15. If the Municipality are not able to assure this and to make it permanent, it means that the Railway Department will have to make their own arrangements for a proper water-supply at Ajmer, or will have to go elsewhere.

16. To move the Workshops would cost the R.-M. Ry. a large outlay, and would no doubt be a loss to many in Ajmer. At the same time there seem to be some advantages in doing so. A narrow valley like Ajmer is not a suitable place to congregate a large body of native work-people. It would be far better to plant them out where the land would be cheap and untainted by use, and unlimited in extent; where a permanent supply of good water could be assured; and where the Workshops could be in touch with both the Broad and the Metre-Gauge systems, and fuel perhaps cheaper.

17. Considering how largely the R.-M. Ry. are concerned in this matter it is in fact a vital question to the R.-M. Ry. It would be satisfactory to know what the views of the R.-M. Ry. authorities are on the subject. Are they satisfied that it is a sound project? And would they be prepared to carry it out for their own interests?

The interests of Ajmer and the Railway seem to be so intimately connected in the matter that it seems to call for hearty mutual co-operation.

Something might perhaps be devised which would benefit the Railway, and at the same time lessen the burden on the town of Ajmer.

If, on the other hand, the Municipality have to bear all the cost, and then for some reason or other the R.-M. Ry. find it necessary hereafter to transfer their establishment elsewhere, the Municipality would find itself saddled with an expensive scheme, which even if successful, might then be difficult to maintain.

JAIPUR,
12th April 1910.

(Sd). S. S. JACOB.

APPENDIX XII.

Sagarmati Water Works Scheme for Ajmer

Mr. Cantin's Report on Pumping Tests, with Six Tables.

INTRODUCTORY.

These tests were undertaken at the instance of the Local Government.

It was proposed to sink 4 wells of 15 feet diameter and to draw 500,000 gallons daily in 16 hours during 6 months, from January until the burst of the monsoon.

The proposal, however, was sanctioned by the Commissioner in March, and only two new wells could be sunk.

The first test was carried out towards the end of May, and operations were stopped on the 28th July, when the rains set in and the Sagarmati began to flow.

It is, of course, impossible to estimate, even approximately, the amount of water held up in the bed of sand near Bhaonta. Although the period of observation was short, it must not be lost sight of that the tests were carried out in the hot weather, and after two consecutive dry years.

The conclusion to be drawn from the results is that the scheme, if taken up, will prove a success.

(Sd.) L. CANTIN,
Executive Engineer,
Ajmer Provincial Division.

Ajmer,
Dated the 17th August 1912.

PERCOLATION WELLS.

Recuperation and Endurance Tests at Bhaonta, in the Sagarmati Valley, Ajmer District.

Topography.

Bhaonta is situate at the south-west corner of the polygon Amba, Kaharpura, Masina, Bhaonta (Plate 1). It is eleven miles from Ajmer and five miles from Saradhna Railway Station.

The Sagarmati flows between two ranges of hills, but near Bhaonta the stream seems to have taken a definite set towards the southern range, and in fact it hugs the foot of the hills.

The Sagarmati is not a perennial stream but flows during 4 or 5 months only in a good year.

From Kaharpura to Masina and on towards the Amba Nullah, the whole country lies buried under blown sand; cultivation is very patchy and wells are few and far between.

On the right bank of the Amba Nullah and in the near vicinity of the trial wells there are many village wells, and cultivation is extensive.

Geology.

The section on line No. I (Plate 2) shows that the spring level is highest near the stream and lowest away from it. The borings were carried out in 1907.

The table of levels (Table 1) tells the same tale. For instance, on the 28th July the spring level in Dol Singh's well was only 6′-11″ against 14′-8″ in Umra's well (Plate 3). On the 15th August the levels rose to 3′-7″ and 12′-10″.

The bed-rock which crops out at old Amba dips steadily towards the river (Line 1, Pit 1, Pit 8, and Line 2, Pit 8, Pit 36), so that the deepest point of the trough is in the river-bed.

The greatest depth of water is to be found there. The best site for a well is on the bank, for the sub-soil water percolates towards the river. The close proximity of the stream will keep the sub-soil saturated, and the water will find its way from the bed into the well.

Lines 2 and 3 are illustrations of the composition of the water-bearing stratum. The great fertility of the surface soil, the numerous village wells which have never been known to fail, the coarseness and the cleanness of the sub-soil, the absence of clay and silt, are very favourable and clear signs of an alluvial tract.

In such a tract the sub-soil water does not flow along subterranean fissures but is contained in the saturated bed of sand, and percolates slowly

through the interstices between the grains. Sand holds an enormous amount of water, as much as 40 per cent., and in alluvial plains the supply is almost inexhaustible.

For a percolation well to be a success the sand must be clean and coarse, and these conditions are fulfilled by the water-bearing stratum at Bhaonta.

It would appear, then, that it is possible to draw any amount of water from a well in a bed of sand, but this is far from being the case.

To draw the water without drawing the sand along with it is the problem which can only be solved by tests.

THE TESTS.

Recuperation Tests.

This test consists in lowering the level of the water in the well to a certain depth by pumping. The well is then allowed to recuperate, and the times taken by the water to rise through a fixed fraction of the maximum depression are noted.

Pumping tests were not attempted. They are unreliable, owing to the difficulty of pumping at a constant draught and under a steady head. The meters used should also be in perfect working order. No meters are rquired for a recuperation test.

If

H' = maximum head of depression.
h' = head at the end of t hours from beginning of recuperation.
A = area of well in square feet.
K = specific capacity of well or yield in cubic feet per hour under a head of 1 foot.

Then

$$\frac{K}{A} t = \log \frac{H}{h}$$

$$\text{or } h = He^{-\frac{K}{A} t} \qquad \text{i}$$

the logs are hyperbolic (*vide* Punjab P. W. D. Paper No. 63).

Also if V is the velocity of inflow in feet per hour

$$V = \frac{K}{A} h \qquad \text{ii}$$

and the yield of the well, in cubic feet per hour, under any head h is Kh.

It is to be distinctly understood that H in equation i may not exceed the critical head of depression.

The object of the tests is to determine the value of K or $\frac{K}{A}$ for each well, and from it to calculate the yield under various heads.

The constant K or $\frac{K}{A}$ can be calculated from equation i after one test; but doubtful or eccentric values must be eliminated.

Determination of K or $\frac{K}{A}$.

This can only be effected by plotting the recuperation curve.

Recuperation Curve.

The recuperation curve is obtained by plotting values of h downwards as ordinates and values of t as abscissae; the axes of reference being the normal surface of the water in the well and the vertical axis of the well. This is the green curve on the plates.

Elimination of eccentric and doubtful values of $\frac{K}{A}$.

The curve lies wholly below its tangent. If therefore, at any point, the tangent coincides with or falls below the curve, the point is doubtful or eccentric and should be eliminated and the corresponding value of $\frac{K}{A}$ rejected.

The intercept of the tangent on the h—axis at a random point (h, t) on the curve is h $(1 + \log \frac{H}{h})$. Hence the tangent is a line through the random point cutting the h—axis at the distance h $(1 + \log \frac{H}{h})$ from the origin.

When the doubtful or eccentric values of $\frac{K}{A}$ have been eliminated, the average of all the correct values is taken, which is the mean $\frac{K}{A}$ for the *test*.

The final value of $\frac{K}{A}$ *for the well* is arrived at by taking a final average of $\frac{K}{A}$ for all the tests.

Calculation of Yield.

The rate, V, in feet per hour, at which the water rises in the well under any head, h, is given by the equation

$$V = \frac{K}{A} h.$$

Hence the yield = velocity × area of well
= V A = K.h.

NOTE:—$\frac{K}{A}$ = yield of well per square foot under a head of one foot in cubic feet per hour.

Velocity Curve.

The curve connecting the velocity and the head is obtained by plotting values of h as abscissae and values of V as ordinates upwards. This is the red curve on the plates.

Theoretically, the recuperation curve is a smooth ascending curve and the velocity curve a straight line. The tests will show that this is far from being the case in reality; but smooth curve and straight line are obtained by adopting a mean value for the co-efficient.—*Vide* Plates B and D in Tables 3 and 4.

The details of the arrangements for carrying out the tests are shown on Plate 3, and the alignment of the trial wells is indicated by the dotted red line on Plate 1.

A Worthington pump, delivery 17,000 gallons per hour, was connected with each well. A 6″ Siemen's meter was fixed on the delivery pipes discharging into masonry tanks. From the tanks the water was carried to a distance through a 9″ pipe, so that it could not percolate back into the wells.

The Wells.

Old Trial Well at boring No. 87.

Sunk in 1908.
Diameter 6½′.
Thickness 1½′.
Original depth 26′.

Pucca masonry, cement plastered internally.

Built on a wooden curb 18″ thick founded on a bed of Kunkor (Line 2, Plate 2), which was broken through to tap the substratum of coarse sand, etc.

Heavily overtaxed in 1908, when it was pumped down to a head of 7′ and again this year; although it was found that sand blew in under a head of 5·5′.

The so-called tests (see Table 2) are given as object lessons. They are of course, valueless. The high, abnormal and erratic values of $\frac{K}{A}$ clearly show that the equation of recuperation is not applicable in this case, the critical head having been exceeded. The depth of sand in the well is 4′, the result of overtaxing.

Trial Well No. I.

Distance from Old Trial Well = 250′.
Diameter 15′.
Depth 18′ – 2″.
Thickness or steining 2′.

Maximum depth of water during period of testing was 9′-2″ on June 5th, 1912.

Pucca masonry, plastered internally.

Sunk during April and May 1912, through 10′ of medium sand and 5′ of coarse sand mixed with gravel. Built on a 9″ wooden curb founded on a bed of conglomerate 3′ thick, which was broken through to tap a substratum of coarse sand, gravel and boulders.

For details of the eight tests (see Table No. 3). The critical head was determined by lowering the head down to 5′ on the 27th May 1912. No sand came into the well. (Test No. 1).

On the 29th May the head was lowered to 6′ and the well immediately allowed to recuperate. The well was overtaxed during 20 minutes only, *viz.*, 14·40—15·00. On the 3rd, 5th, and 7th June, sand was found in the well after the tests, although the maximum head was only 3′, 3′ and 4′ respectively. (*Vide* Tests Nos. 4, 5 and 7).

The critical head is therefore between 5′ and 6′; say 5·5′.

The value of $\frac{K}{A}$ for this well is 2·29.

The calculated yields under heads varying from 6″ to 5′ are given in the last column of Table A.

The recuperation and velocity curves are plotted on Plate B.

Trial Well No. 2.

Distance from Well No. 1 = 250′.
Do. Old Trial Well = 500′.
Depth 20½′.

Maximum depth of water in well during *period of testing* was 8′-8½″ on 22-6-1912.

Of same dimensions as Well No. 1.

Sunk in April and May 1912 through 12′ of fine and medium sand and 5′ of coarsish sand and small gravel. Built on a 9″ wooden curb, founded on a bed of conglomerate and kunker 3′ thick which, was broken through in the hope of tapping a coarse substratum as in the case of Well No. I; but only bed rock was struck. For details of tests, see Table 4.

The value of $\frac{K}{A}$ is 1·63 and the calculated yields under heads ranging from 6″ to 5′ are to be found in the last column of Table C.

This well was never overtaxed and no sand found its way in.

Its yield is much lower than that of Well No. 1.

Endurance Tests.

These tests were carried out with a view to ascertaining whether the actual yield would approximate the calculated yield, and also whether continual pumping would affect the spring level of the wells.

Actual and calculated yield.

From Table 5 it appears that the total actual yield of Well No. 1 under an average head of 3′ for 21 days of 16 hours is 86 per cent. of the calculated yield.

The total actual yield of the same well under an average head of 4′ for 10 days is 96 per cent. of the calculated yield.

In the case of Well No. 2, the percentage is 94 for 14 days under a head of 3′ and 90 for 8 days under a head of 4′.

It must be borne in mind that some time is lost at the beginning of the tests in lowering the level to the required head.

Taking into consideration the difficulty of pumping at a constant drought under a steady head, and also meter errors these results are satisfactory on the whole. Practical reliability and not absolute accuracy is claimed.

Effect of pumping on spring level.

The Level Chart (Plate 4) shows at a glance the effect of continual pumping on the spring level of the trial wells.

The levels were recorded daily at the beginning of the tests.

Generally.—There is a steady fall when the spring level is lowered by 4′ and pumping kept up for 16 or even 12 hours under this head, *i.e.*, the wells do not recover completely in 12 hours; the drop being greater after a 16 hour than after a 12 hour test. Under a head of 3′ total recuperation takes place in 8 hours, *i.e.*, the spring level has a tendency to remain stationary; *vide* Charts A and B, July 7-16.

The level rises whenever the wells are allowed to rest (Chart A, June 22; Charts A and B, July 2, 18, 26 and 28); the recuperation in 36 hours after a 16 hour test under a head of 4′ averaging 4″ (July 25-28).

The behaviour of the water-table is a very important consideration in the case of shallow wells, for it is obvious that the spring level cannot be continuously lowered. After a time the water level will fall to the bottom of the well, and the drainage cone will be drained dry. Hence it would appear safer to pump under a head of 4′ every other day than under a 3′ head daily for 16 hours.

The number of wells would, of course, be doubled.

NOTE.—The levels on June 16, 17, 18, 19 and 20 (Chart B) seem inconsistent but the inconsistency is only apparent; for, from the 1st to the 14th June, pumping was kept up daily for 12 hours under a 3′ head, while the well was being sunk to reduce the depth of water and facilitate dredging, so that the well was less severely taxed during the short recuperation tests than during the process of sinking.

INTERFERENCE OF WELLS.

Chart C.

Well A, Diameter 7′ (Plate 3) is 44′ from Well No. 2, centre to centre.

Its chart is an excellent illustration of interference, and it reflects all the vicissitudes of the latter well and the vagaries of Chart B.

In fact, Well A is a satellite of the larger primary Well No. 2.

Chart D.

This chart illustrates the general behaviour of the water-table.

Madho's Well (Plate 3), being isolated from the other wells was uninfluenced by them. It was very little used for irrigation purposes.

Cone of Depression.

The equation of the cone is $h = He^{-MX}$ where h′ is the depth below normal spring level at any distance X′ from the outside of the steining; H′ is the maximum depression, equal to or less than the critical head, and m a co-efficient.

The curve is not in reality a cone but it is similar to the recuperation curve, the equation of which is $h = He^{-\frac{K}{A}t}$.

In Table 6, h (in column 2) is the drop observed in Well A, when the level in the Well No. 2 was lowered H′ (column 3).

The wells are 44′ apart, centre to centre, and since the diameter of Well No. 2 is 15′ and the steining 2′ thick, $x = 44 - 9{\cdot}5 = 34{\cdot}5'$.

The average value of $m = {\cdot}05$ and the equation of the cone for Well No. 2 is $h = He^{-{\cdot}05x}$.

The cones of Well No. 2, corresponding to heads of 4 and 5′ are represented respectively by the upper and lower curves of Plate E.

If the maximum interference permissible is $\frac{1}{10}''$ (practically *nil*) when the head of depression is 4′ wells in series should be about 250′, centre to centre.

For in this case $X = \frac{1}{{\cdot}05} \log e \; 480 = 123{\cdot}4'$ assuming the value of m to be the same for all the wells.

The drop at 125′ from the centre of Well No. 2, when pumped down to a head of depression of 5′ is 0·2″ only.

Hence the trial wells practically do not interfere with each other.

If the wells are 150′, centre to centre, the interference under a head of 5′ is 2·4″ and 0·6″ if the spacing is 200′.

The drop can be scaled off the curves on Plate E. Thus at 46′ the drop is 6″, and if this is the maximum interference allowable the wells should be placed 92′ apart.

Conclusion.

General Recommendations.

The wells should be near the bank. The position of each well should be fixed by trial borings to avoid founding it on rock as in the case of Well No. 2, which has a much smaller yield than Well No. 1.

Site of Wells

Spacing.

200′ (feet), centre to centre.

Depth of Wells.

The wells should be sunk down to the kunker or conglomerate bed (Plate 2, Line 2), which should be broken through to tap the coarse substratum.

This is the practice of the native well-sinkers of the locality.

Curbs.

The new trial wells rest on a wooden curb 9″ in thickness.

Iron curbs 18″ deep are recommended. The cutting edge would facilitate sinking and the cost would be the same as for wooden curbs, which are very expensive.

Strainers.

The use of copper gauze box-strainers let into the steining and packed with kunkor is strongly advocated. Fine sand will at first come into the well, but it can easily be dredged out, and after a time the steining will be surrounded by coarse sand.

The friction between the grains of *sand will be considerably* reduced and the yield greatly improved.

Working head.

The working head to be 4′ or less.

Critical head.

On no account should the head exceed 5′, which is the average critical head for sand. If this limit is exceeded *fine sand will blow in* and the well might be irreparably damaged.

Working hours.

Fourteen. Each well to be pumped every other day.

Number of Wells.

The daily consumption of Ajmer, exclusive of the Railway, is estimated at 500,000 gallons.

The yield of Well No. 1 under the working head for 16 hours is 162,000 gallons (Table 3).

The yield of Well No. 2 is 115,000 (Table 4).

Assuming $\frac{K}{A}$ for the old trial well to be the same as for Well No. 1, its specific capacity (K) is $K = 2{\cdot}29 \times 33{\cdot}2 = 76$ C.ft. per hour, and the yield for 16 hours $= 76 \times 4 \times 16 \times \frac{25}{4} = 30{,}400$ gallons.

The aggregate yield of the three wells is 307,000 gallons.

If it is contemplated to utilize these to make up for the deficit of 200,000, at least one more well equal in diameter to the new trial wells would be required, and pumping would have to be kept up for 17 hours.

It is therefore proposed to have two sets of wells, which would be drawn upon on alternate days.

The first set would consist of Well No. 1, No. 2 and two new wells of 15′ diameter.

One of the new wells could be sunk round the old trial well (which would be dismantled), for it is very favourably placed.

The second set would consist of 4 new wells 15′ in diameter.

Altogether 6 new wells would be required.

Fourteen hours' pumping would suffice and a fair margin of safety secured.

It is presumed that the specific capacity of the proposed new wells will be equal to that of Well No. 1.

This assumption is on the safe side if the wells are sunk in the close proximity of the Sagarmati.

LEVELS OF WELLS.

TABLE 1.

Depth of Water Table below Ground Level in Wells in the Vicinity of Test Wells.

Date.	Old Well.		Well near Old Well.		Madho's Well.		Umra's Well.		Goma's Well.		Well A.		Well No. 2.		Well No. 1.		Dolsing's Well on bank of Sagarmati.	Bheron Baksh's Well.	Remarks.
	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.			
12-6-12 ...	8	0	10	0	12	0	14	3	12	9	13	3	...		9	10			
13-6-12 ...	8	1	10	1	12	1	14	4	12	9	13	3	...		9	10			
14-6-12 ...	8	2	10	2	12	1	14	4	12	10	13	3	...		9	10½			
15-6-12 ...	8	3	10	3	12	2	14	5	12	11½	13	4	12	3	9	11			
16-6-12 ...	8	3	10	3	12	2	14	3	12	11	13	0	11	11	Do.				Sagarmati dry.
17-6-12 ...	8	3	10	3	12	2	14	3	12	11	13	0	Do.		Do.				
18-6-12 ...	8	3	10	3	12	3	14	3½	12	11	13	0	Do.		Do.				
19-6-12 ...	8	3	10	3½	12	3	14	4	12	11	13	0	Do.		9	10½			
20-6-12 ...	8	3	10	3½	12	3	14	3	12	11	13	0	Do.		...				
21-6-12 ...	8	2	10	2½	12	3	14	3	12	11	12	10	11	10	...				

LEVELS OF WELLS.

TABLE 1—(*Contd.*).

Depth of Water Table below Ground Level in Wells in the Vicinity of Test Wells.

Date.	Old Well.		Well near Old Well.		Madho's Well.		Umra's Well.		Goma's Well.		Well A		Well No. 2.		Well No. 1.		Dolsing's Well on bank of Sagarmati.		Bheron Baksh's Well.		Remarks.
	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft	In.	Ft.	In.	Ft.	In.	Ft.	In.	
22-6-12 ...	8	1	10	1	12	2	14	2½	12	10	12	10	11	9½	9	6½					
23-6-12 ...	8	2	10	2	12	2	14	4	13	0	13	2	12	2	9	10					
24-6-12 ...	8	4	10	4	12	3	14	5	13	2	13	3	12	4	9	11					
25-6-12 ...	8	5	10	5	12	4	14	7	13	3	13	6	12	7	10	2					
26-6-12 ...	8	6	10	6	12	5	14	8	13	4	13	7	Do.		10	3					Sagarmati dry.
27-6-12 ...	8	6	10	6	12	6	14	9	13	4	13	8	Do.		10	4					
28-6-12 ...	8	6½	10	7	Do.		Do.		13	4½	Do.		12	8	10	5					
29-6-12 ...	Do.		Do.		Do.		Do.		13	5	Do.		12	9	Do.						
30-6-12 ...	8	7	Do.		12	7	14	10	13	6	13	9	Do.		Do.						
1-7-12 ...	Do.		10	7½	Do.		Do.		Do.		Do.		12	8½	Do.						

2-7-12 ...	Do.	Do.	Do.	14 8	13 4	Do.	12 8	10 4			
3-7-12 ...	8 8	10 8	12 7	14 10	13 6	13 10	Do.	10 5	7 1		
4-7-12 ...	8 9	10 9	12 8	14 11	13 7	13 10	Do.	10 4	7 2		
5-7-12 ...	Do.	Do.	Do.	15 0	13 8	14 0	Do.	Do	Do.		
6-7-12 ...	Do.	Do.	12 9	Do.	Do.	Do.	12 10	10 6	Do.		
7-7-12 ...	8 10	10 10	Do	Do.	13 8	Do.	13 0	10 8	Do.		
8-7-12 ...	8 10	10 10	12 9	15 0	13 8	14 0	13 0	10 8	7 3	7 9	
9-7-12 ...	Do.	Do.	Do.	15 1	Do.	Do.	Do.	Do.	Do.	Do.	
10-7-12 ...	Do.	Do.	Do.	15 0	Do.	Do.	Do.	Do.	Do.	Do.	
11-7-12 ...	Do.	Do.	Do.	Do.	Do.	Do.	Do.	Do.	Do.	Do.	Sagarmati dry.
12-7-12 ...	Do.	Do.	Do.	Do.	Do.	Do.	Do.	Do.	Do.	Do.	
13-7-12 ..	Do.	Do.	Do.	Do.	Do.	Do.	Do.	Do.	Do.	Do	
14-7-12 ...	Do.	Do.	12 10	Do.	Do.	Do.	Do.	Do	Do	Do.	
15-7-12 ...	Do.	Do.	Do.	Do.	13 7	Do.	Do.	Do.	Do.	Do	
16-7-12 ...	Do.	Do.	Do.	Do.	Do.	Do.	Do.	Do.	Do.	Do.	
17-7-12 ...	Do.	Do.	Do.	Do.	Do.	13 10	12 11	10 7	Do.	7 8	

LEVELS OF WELLS.

Table 1—(*Contd.*).

Depth of Water Table below Ground Level in Wells in the Vicinity of Test Wells.

Date.	Old Well.		Well near Old Well.		Madho's Well.		Umra's Well.		Goma's Well.		Well A.		Well No. 2.		Well No. 1.		Dolsingh's Well on bank of Sagarmati.		Bheron Baksh's Well.		Remarks.
	Ft.	In.	Ft	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft	In.	
18-7-12 ...	8	8	10	9	12	9	14	9	13	5	13	6	12	3	10	3	7	3	7	6	
19-7-12 ...	8	9	Do.		Do.		14	10	Do.		13	8	12	6	10	5	Do.		Do.		
20-7-12 ...	Do.		10	9½	Do.		Do.		13	5½	Do.		Do.		Do.		Do.		Do.		
21-7-12 ...	Do.		10	10	Do.		Do.		13	6	13	9	12	7	10	6	7	3½	7	6½	
22-7-12 ...	Do.		Do.		Do.		Do.		Do.		Do.		Do.		Do.		7	4	7	7	Sagarmati dry.
23-7-12 ...	8	9½	Do.		12	9½	14	10½	Do.		Do.		Do.		Do.		Do.		Do.		
24-7-12 ...	Do.		Do.		Do.		Do.		Do.		13	9½	12	7½	10	6½	Do.		Do.		
25-7-12 ...	8	10	Do.		12	10	14	11	13	7	13	10	12	8	10	7½	Do.		Do.		
26-7-12 ...	8	9	10	9	12	9	14	9	13	5½	13	6	12	4	10	3	7	3	7	6	
27-7-12 ...	Do.		Do.		Do.		14	10	13	6	13	9	12	7	10	6	Do.		Do.		

28-7-12 ...	8	7	10	7	12	8	14	8	13	4	13	5	12	3	10	3	6	11	7	4	Last test, monsoon established.
29-7-12 ...	Do.		Do.		Do.		14	9	13	4½	13	7	12	5	10	4	6	8	Do.		
30-7-12 ...	8	4	10	5	12	7	14	7	13	3	13	2½	12	0	10	0	6	6	7	2	
31-7-12 ...	8	2	10	3	12	5	14	5	13	1	13	0	11	10	9	9	6	5	7	0	
1-8-12 ...	8	0	10	1	12	4	14	4	13	0	12	11	11	9	9	8	6	3	6	10	
2-8-12 ...	7	11	9	11	12	3	14	3	12	11	12	10	11	8	9	7	6	2	6	9	
3-8-12 ...	7	10	9	10	12	2	14	2	12	10	12	8	11	7	9	5	6	1	6	7	
4-8-12 ...	7	9	9	9	12	1	14	1	12	9	12	7	11	6	9	4	6	0	6	6	
5-8-12 ...	7	8	9	8	12	0	14	0	12	8	12	6	11	5	9	3	6	·0	6	5	
6-8-12 ...	7	7	9	7	11	11	13	11	12	7	12	6	11	4	9	2	5	11	6	4	
7-8-12 ...	7	6	9	6½	11	10	13	10	12	6	12	5	11	3	9	1	5	10	6	3	
8-8-12 ...	Do.		9	6	Do.		Do.		Do.		12	4	11	2	9	0	Do.		Do.		Flood depth in Sagarmati = 2′.
9-8-12 ...	7	5	9	5	11	9	13	9	12	5	12	3	11	1	8	11	5	8	6	2	
10-8-12 ...	7	4	9	4	11	9	Do		Do.		Do.		Do.		Do.		5	7	6	0	Sagarmati mining 3½′ deep.
11-8-12 ...	6	10	8	10	Do.		Do.		Do.		12	2	11	0	8	9	4	6	5	4	Flood depth = 1½′.
12-8-12 ...	6	5	8	4	11	4	13	7	12	3	11	10	10	10	8	4	3	10	4	9	Flood depth 6″.

LEVELS OF WELLS.

Table 1—(*Contd.*).

Depth of Water Table below Ground Level in Wells in the Vicinity of Test Wells.

Date.	Old Well		Well near Old Well.		Madho's Well		Umra's Well.		Goma's Well.		Well A		Well No. 2.		Well No. 1.		Dolsing's Well on bank of Sagarmati		Bheron Baksh's Well.		Remarks.
	Ft.	In	Ft.	In.	Ft.	In	Ft	In.	Ft.	In.	Ft	In	Ft	In.	Ft.	In.	Ft.	In.	Ft.	In.	
13-8-12 ...	6	1	8	0	11	3	13	4	12	0	11	6	10	6	7	11.	3	8	4	7	Flood depth 6".
14-8-12 ...	5	10	7	10	10	10	13	1	11	9	11	3	10	3	7	8	3	8	1	5	
15-8-12 ...	5	9	7	9	10	8	12	10	11	7	11	1	10	0	7	6	3	7	4	3	

TABLE 2.

Recuperation Test No. 1.

Date, 28th May 1912.

OLD EXPERIMENTAL WELL.

Diameter = $6\frac{1}{2}'$.

$$\frac{K}{A} T = \log \frac{H}{h}.$$

$H = 6\frac{3}{4}'$.

h.	T.	$\log \frac{H}{h}$.	$\frac{K}{A} = \frac{V}{h}$.	Remarks.
$H = 6\frac{3}{4}$	12·15	...	...	
·9 H	12·15½	0·11	13·2	
·7 H	12·16½	·36	14·4	
·6 H	12·17½	·51	12·2	
·4 H	12·18¾	·92	14·72	
·3 H	12·20½	1·20	13·1	
·15 H	12·23	1·89	13·1	
0	13·00	...	...	

TABLE 2—(*Continued*).

Recuperation Test No. 2.

Date, 1st June 1912.

OLD EXPERIMENTAL WELL.

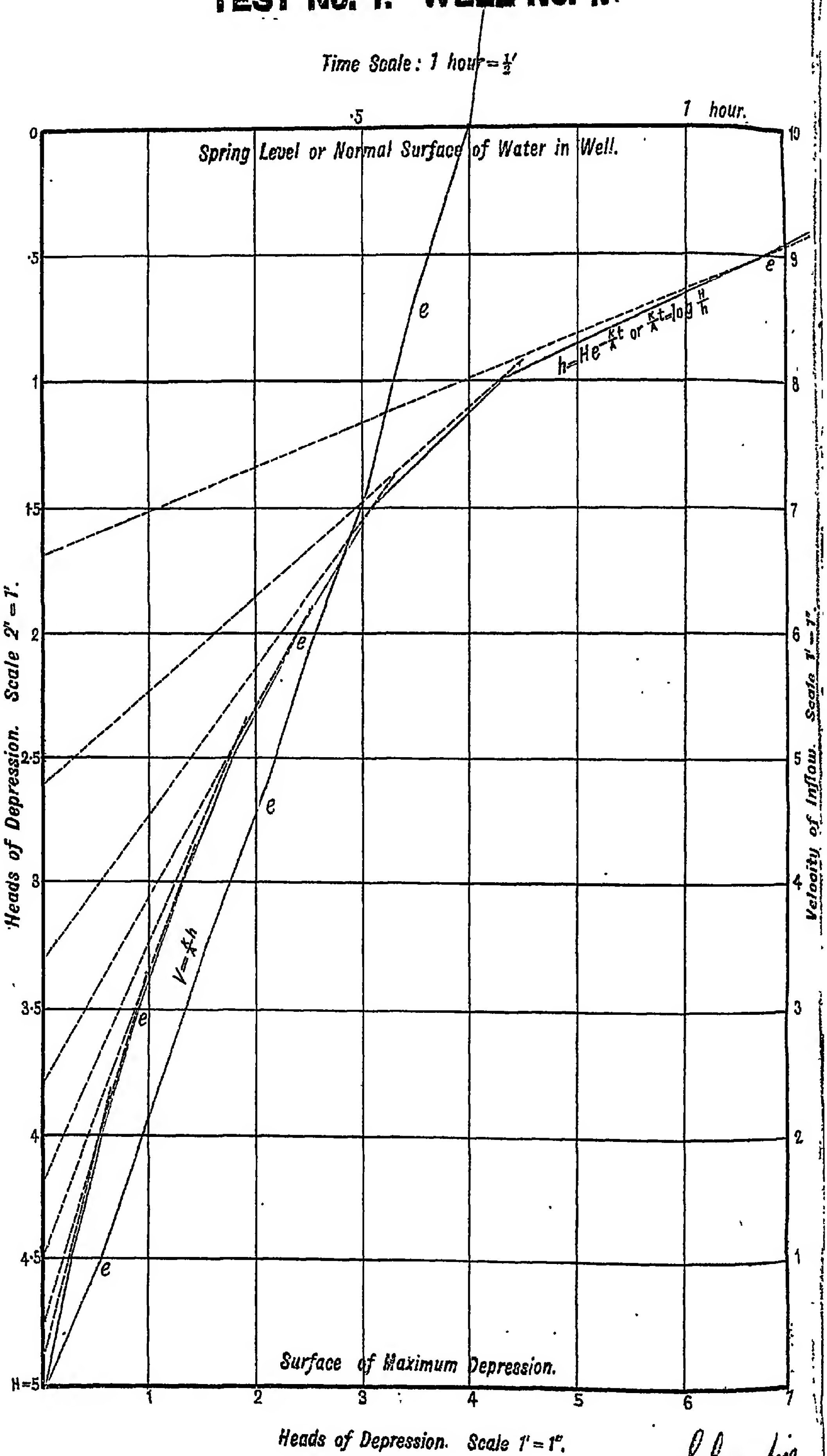
Diameter = $6\frac{1}{2}'$.

$$\frac{K}{A} T = \log \frac{H}{h}.$$

$H = 7'$.

h.	T.	$\log \frac{H}{h}$.	$\frac{K}{A} = \frac{V}{h}$.	Remarks.
7′ = H … …	6·42	…	…	
6 … …	6·43½	·15	6·00	
5 … …	6·44½	·34	8·16	
4 … ..	6·45½	·56	9·60	
3 … ..	6·46½	·85	11·33	
2 … …	6·48½	1·25	11·54	
1 … …	6·52	1·95	11·70	
0 … …	8·56	…	…	

TEST No. 1. WELL No. 1.



h. Cantin
3/4/12

TABLE 3.

Recuperation Test No. 1.

Date, 27th May 1912.

NEW WELL No. 1.

Diameter = 15 feet.

Area (A) = 176·71 sq. ft.

$$\frac{K}{A}T = \log\frac{H}{h}.$$

$H = 5'$.

h.	Timings.	$\log\frac{H}{h}$.	$h\left(1+\log\frac{H}{h}\right)$	$\frac{K}{A}$.	V.	Yield per hour in gallons.	Remarks.
H = 5′ ...	8·28	...	......	...	...	...	
4·5...	8·30¼	0·11	5	2·93	13·19	14,562	Doubtful.
4·0...	8·33¼	0·22	4·9	2·51	10·04	11,084	
3·5...	8·36¾	0·36	4·8	2·47	8·65	9,550	Eccentric point.
3·0...	8·41	0·51	4·5	2·34	7·02	7,750	
2·5...	8·45½	0·69	4·2	2·37	5·93	6,547	
2·0...	8·52	0·92	3·8	2·30	4·60	5,078	Eccentric.
1·5...	8·59	1·20	3·3	2·32	3·48	3,842	
1·0...	9·11	1·61	2·6	2·25	2·25	2,484	
0·5 ..	9·36	2·30	1·7	2·03	1·02	1,126	Eccentric.
0 ...	12·31	...	......	...	..	...	

NOTE.— Mean $\frac{K}{A} = \frac{1}{5}$ (2·51 + 2·34 + 2·37 + 2·32 + 2·25) = 2·36.

TABLE 3—(*Continued*).

Recuperation Test No. 2

Date, 29th May 1912.

NEW WELL NO. 1.

Diameter = 15 feet.

Area (A) = 176·71 sq. ft.

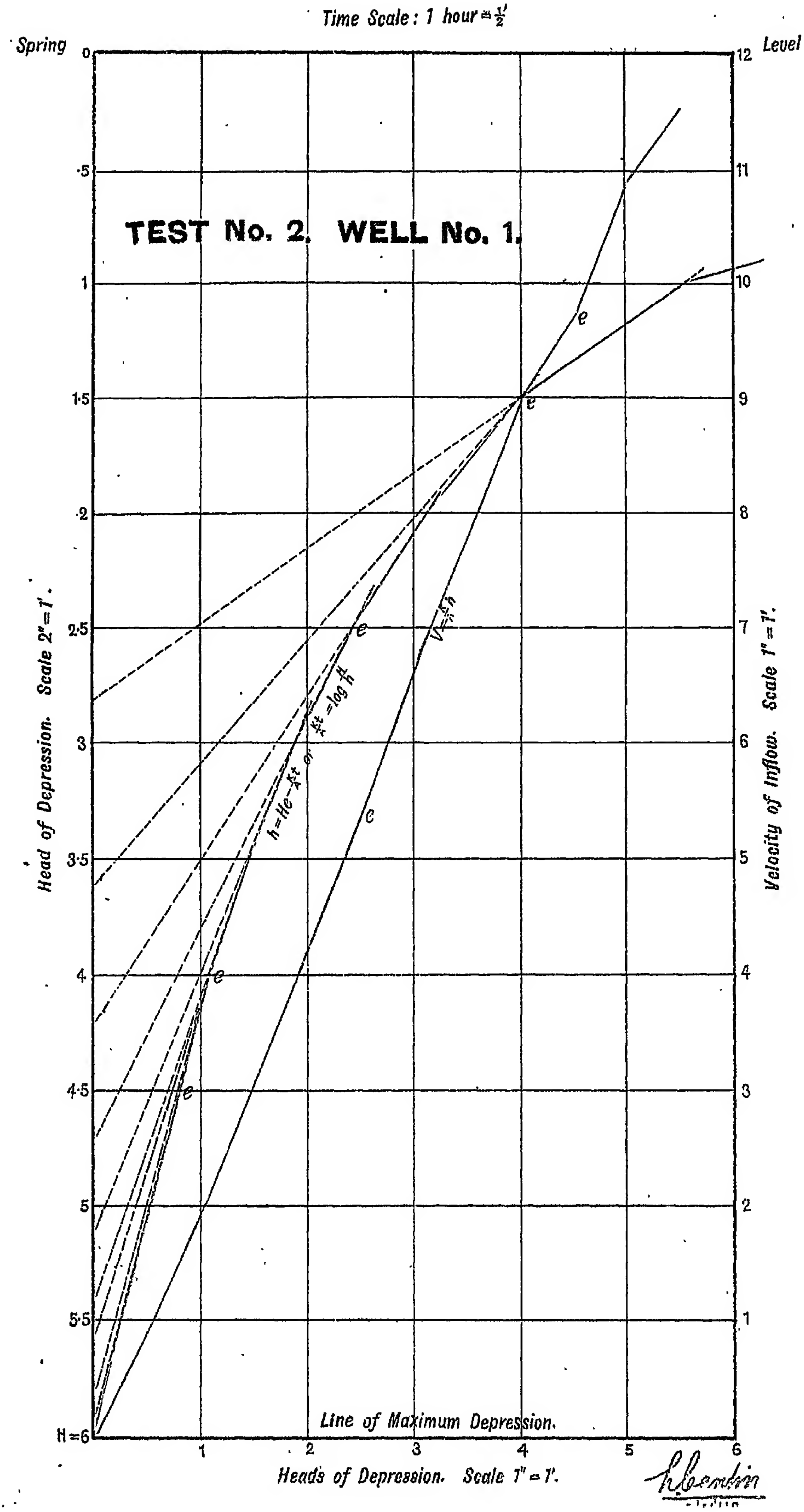
$$\frac{K}{A}T = \log\frac{H}{h}.$$

H = 6′.

h.	Timings.	$\log\frac{H}{h}$.	$h\left(1+\log\frac{H}{h}\right)$.	$\frac{K}{A}$.	V.	Yield per hour in gallons.	Remarks.
H = 6′ ...	3·00 p.m.	...	......	...	...	...	
5·5...	3·2 ½	·09	6·0	2·10	11·55	12,751	
5·0...	3·5	·18	5·9	2·18	10·90	12,034	
4 5...	3·8	·29	5 8	2·16	9·72	10,731	Eccentric.
4·0...	3·11	·41	5·6	2·26	9·04	9,980	Eccentric.
3·5...	3·14½	·54	5·4	2·23	7·81	8,622	
3·0...	3·18¾	·69	5·1	2·22	6·66	7,353	
2·5...	3·24¼	·88	4·7	2·16	5·40	5,962	Eccentric.
2·0...	3·31¼	1·10	4·2	2·11	4·22	4,659	
1·5...	3·40	1·39	3·6	2·08	3 12	3,444	
1·0...	3·55¼	1·79	2·8	1·94	1·94	2,142	
0·5...	4·29	2·12	1 6	1·73	·87	960	
0·0...	9·00	...	......	...	...	...	

NOTE.—Mean $\frac{K}{A} = \frac{1}{8}$ (2·10 + 2·18 + 2·23 + 2·22 + 2·11 + 2·08 + 1·94 + 1·73) = 2·07.

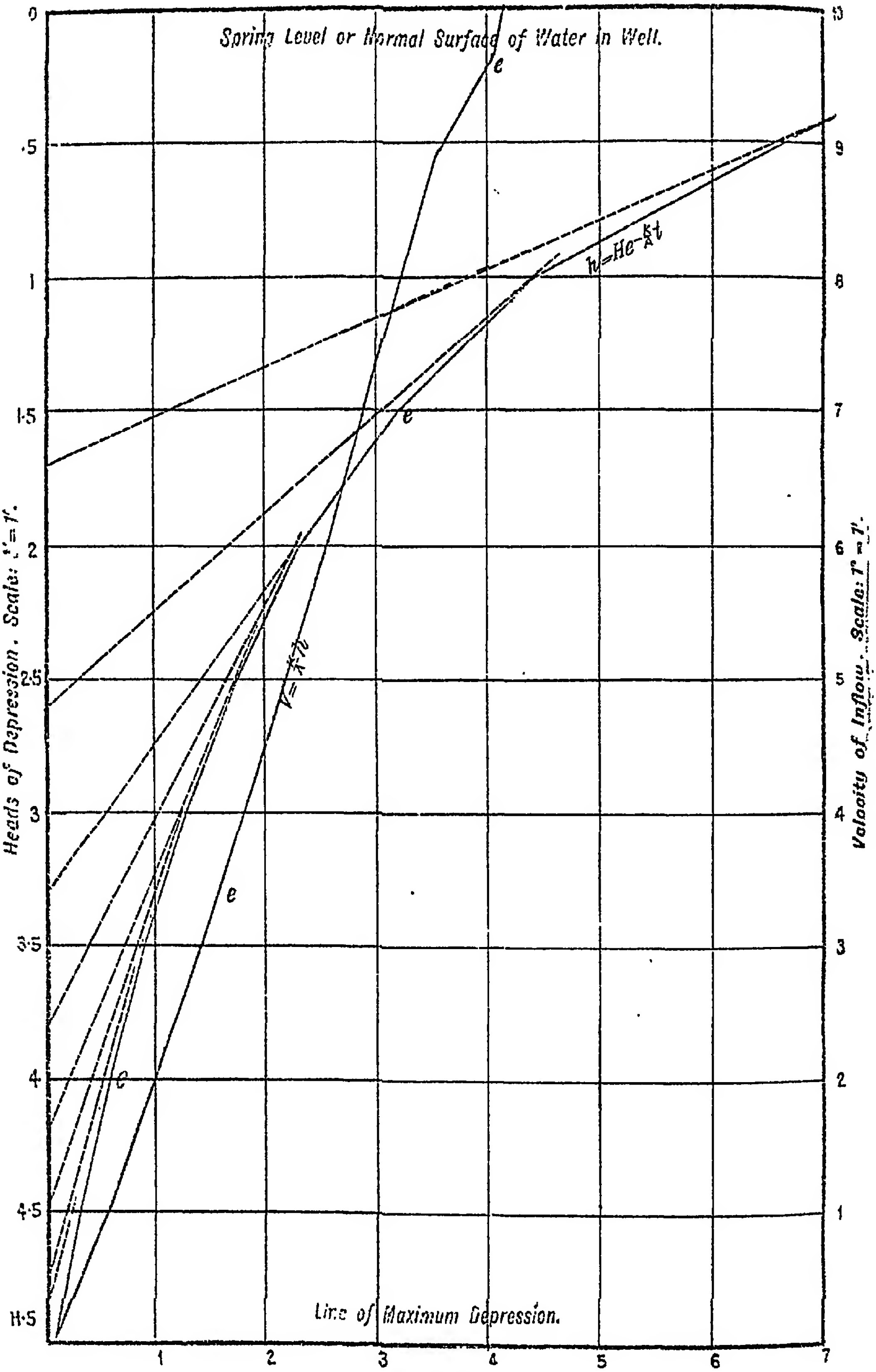
The time taken in covering the head from 5′ to 6′ was only 20′, *viz.*, from 2·40 p.m. to 3 p.m.; thus the well was not long overtaxed.



Time Scale: 1 hour = 1/2'
Spring
Level
TEST No. 2. WELL No. 1.
Head of Depression. Scale 2" = 1'.
Velocity of Inflow. Scale 1" = 1'.
h = He^{-k/A t} or k/A t = log H/h
V = k/A h
e
Line of Maximum Depression.
Heads of Depression. Scale 1" = 1'.
H = 6

TEST No. 3.

Time Scale: 1 hour = 1″.



Heads of Depression. Scale: 1″ = 1′.

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TABLE 3—(*Continued*).

Recuperation Test No. 3.

Date, 31st May 1912.

NEW WELL No. 1.

Diameter = 15 feet.

Area (A) = 176·71 sq. ft.

$$\frac{K}{A} T = \log \frac{H}{h}.$$

H = 5′.

h.	Timings.	$\log \frac{H}{h}$.	$h\left(1 + \log \frac{H}{h}\right)$.	$\frac{K}{A}$.	V.	Yield per hour in gallons.	Remarks.
H = 5′ ...	7·47	...	...	...	...	...	
4·5...	7·49½	0·11	5·00	2·64	11·88	13,116	
4·0...	7·52½	0·22	4·88	2·40	9·60	10,598	Eccentric.
3·5...	7·55½	0·36	4·76	2 54	8·89	9,815	
3·0...	7·59¼	0·51	4·53	2·49	7·47	8,247	
2·5...	8·4 ¼	0·69	4·22	2·40	6·00	6,624	
2·0...	8·9 ¾	0·92	3·84	2·32	4·64	5,123	
1·5...	8·18¾	1·20	3·3	2·27	3·41	3,765	Eccentric.
1·0...	8·30¾	1·61	2·61	2·20	2·20	2,429	
0·5...	8·53½	2·30	1·65	2·07	1·04	1,148	
0·0...	12·32	...	...	...	...	...	

NOTE.—Mean $\frac{K}{A} = \frac{1}{7}$ (2·64 + 2·54 + 2·49 + 2·40 + 2·32 + 2·20 + 2·07) = 2·38.

TABLE 3—(*Continued*).

Recuperation Test No. 4.

Date, 3rd June 1912.

NEW WELL No. 1.

Diameter = 15 feet.

Area (A) = 176·71 sq. ft.

$$\frac{K}{A}T = \log\frac{H}{h}.$$

H = 3′.

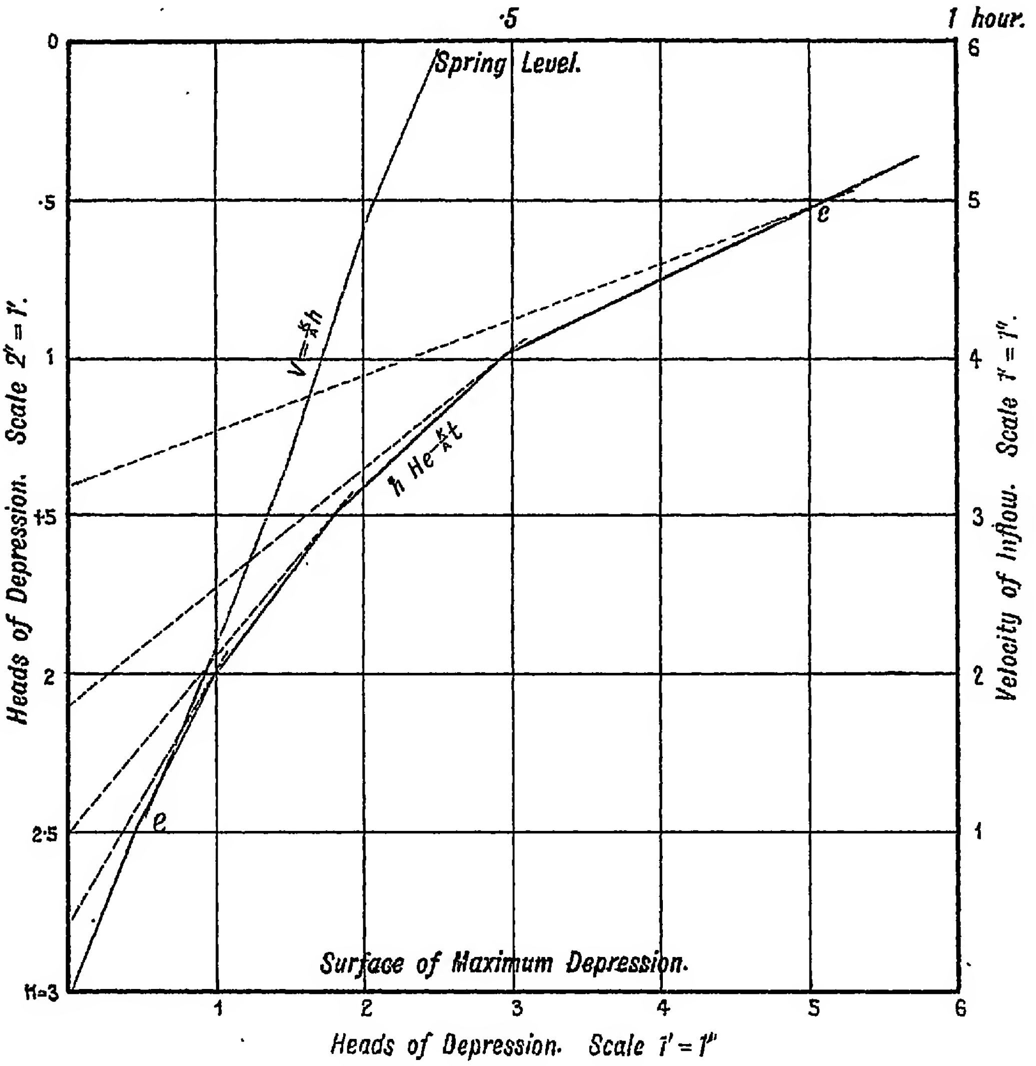
h.	Timings.	$\log\frac{H}{h}$.	$h\left(1+\log\frac{H}{h}\right)$.	$\frac{K}{A}$.	V.	Yield per hour in gallons.	Remarks.
H = 3′ ...	12·31½	...	...	...	...	...	
2·5 ..	12·36	0·18	3·0	2·40	6	6,624	
2·0...	12·41½	0·41	2·8	2·46	4·92	5,432	
1·5...	12·49½	0·69	2·5	2·30	3·45	3,809	
1·0...	13·1	1·10	2·1	2·24	2·24	2,473	
0·5...	13·23	1·79	1·4	2·09	1·05	1,160	Eccentric.
0·0...	20·30	...	...	...	...	...	

NOTE.—Mean $\frac{K}{A} = \frac{1}{4}$ (2·40 + 2·16 + 2·30 + 2·24) = 2·35.

1″ of sand was found in the well, due to over taxing on 29-5-12, when the head was lowered to 6′. This shows that the sand once disturbed behaves like quick sand and blows in even at low heads.

TEST No. 4. WELL No. 1.

Time Scale: 1 hour = ½'.



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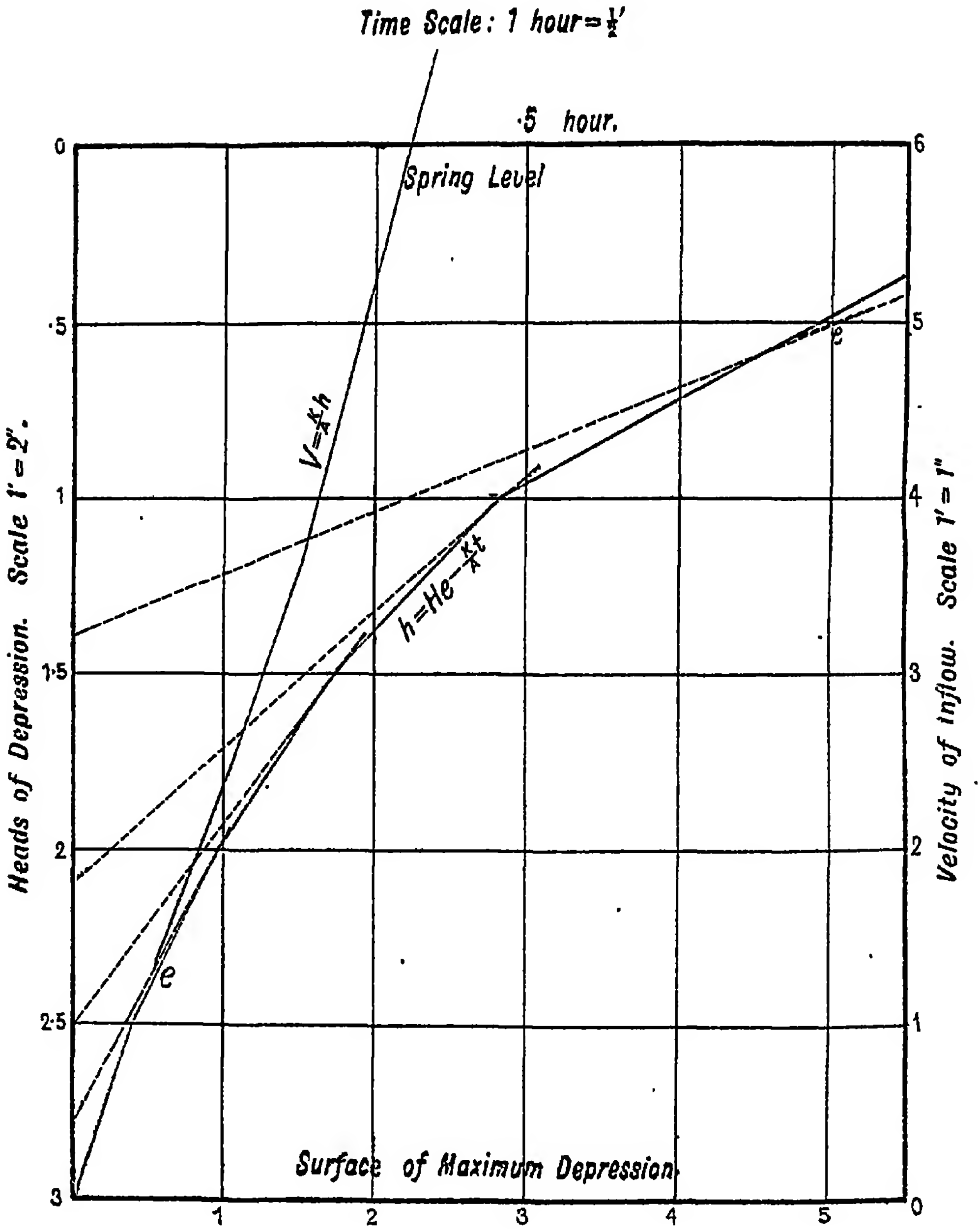
TEST No. 5. WELL No. 1.



Heads of Depression. Scale 1' = 1"

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TABLE 3—(*Continued*).

Recuperation Test No. 5.

Date, 5th June 1912.

NEW WELL No. 1.

Diameter = 15 feet.

Area (A) = 176·71 sq. ft.

$$\frac{K}{A}T = \log\frac{H}{h}.$$

H = 3′.

h.	Timings.	$\log\frac{H}{h}$.	$h\left(1+\log\frac{H}{h}\right)$.	$\frac{K}{A}$.	V.	Yield per hour in gallons.	Remarks.
H = 3′ ...	7·45½	...	...	...	...	...	
2·5...	7·49½	0·18	3·0	2·70	6·75	7,452	
2·0...	7·55	0·41	2·8	2·59	5·18	5,719	
1·5...	8·3	0·69	2·5	2·36	3·54	3,908	
1·0...	8·14	1·10	2·1	2·32	2·32	2,561	
0·5...	8·35½	1·79	1·4	2·37	1·19	1,314	Eccentric.
0 ..	12·55	...	...	...	...	...	

NOTE.—Mean $\frac{K}{A} = \frac{1}{4}(2{\cdot}70 + 2{\cdot}59 + 2{\cdot}36 + 2{\cdot}32) = 2{\cdot}49$.

1″ of sand was found in the well.

TABLE 3—(*Continued*).

Recuperation Test No. 6

Date, 7th June 1912.

NEW WELL No. 1.

Diameter = 15 feet.

Area (A) = 176·71 sq ft.

$$\frac{K}{A}T = \log\frac{H}{h}.$$

H = 4′.

h.	Timings.	$\log\frac{H}{h}$.	$h\left(1+\log\frac{H}{h}\right)$.	$\frac{K}{A}$.	V.	Yield per hour in gallons.	Remarks.
H = 4′ ...	9·33½	...	...	...	...	...	
3·5...	9·37	·13	4·0	2·23	7·80	8,611	
3·0...	9 41	·29	3·9	2 32	6·96	7,684	
2·5...	9·46	·47	3·7	2·26	5·64	6,227	Eccentric.
2·0...	9·52	·69	3·4	2·24	4·48	4,946	
1·5...	10·1	·98	3·0	2·14	3·21	3,544	Eccentric.
1·0...	10·14½	1·37	2·4	2·05	2 05	2,263	
0·5...	10·45	2·08	1·5	1·75	0 87	..	Eccentric.
·25...	11·57	2·77	·9	...	...	..	
0 ...	...	...	...	...	...	...	

NOTE.—Mean $\frac{K}{A} = \frac{1}{4}$ (2·23 + 2·32 + 2·24 + 2·05) = 2·21.

TEST No. 7 WELL No. 1.

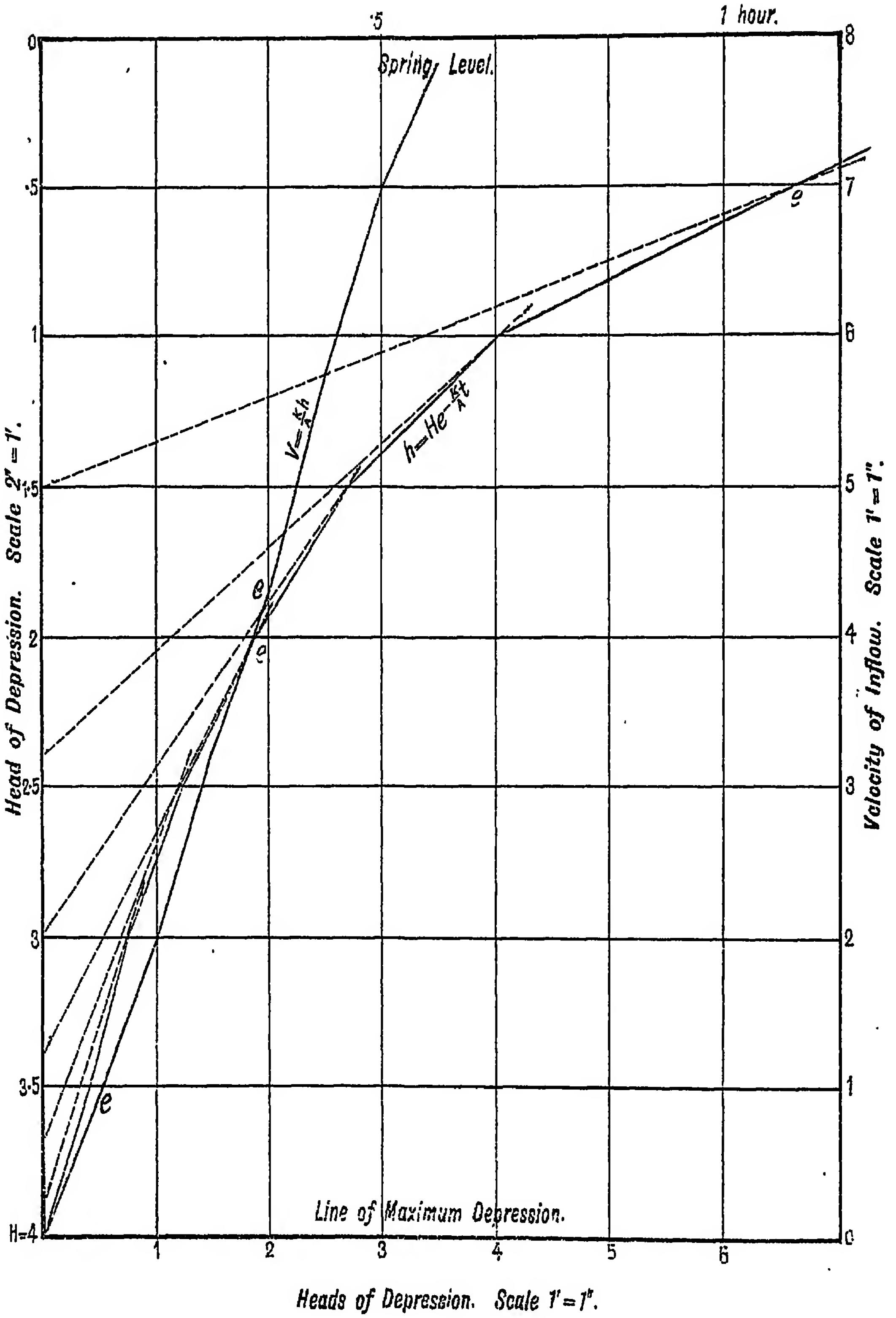

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TABLE 3.—(*Continued*).

Recuperation Test No. 7.

Date, 8th June 1912.

NEW WELL NO. 1.

Diameter = 15 feet.

Area (A) = 176·71 sq. ft.

$$\frac{K}{A}T = \log\frac{H}{h}.$$

H = 4′.

h.	Timings.	$\log\frac{H}{h}$.	$h\left(1+\log\frac{H}{h}\right)$.	$\frac{K}{A}$.	V.	Yield per hour in gallons.	Remarks.
H = 4′ ...	8·44	...	..	...	...	...	
3·5..	8·47½	·13	4·0	2·23	7·80	8,611	
3·0...	8·51½	·29	3·9	2 32	6·96	7,684	
2·5...	8·56	·47	3·7	2·35	5·70	6,293	
2·0...	9·3	·69	3·4	2·18	4·25	4,691	Eccentric.
1·5...	9·11	·98	3·0	2·18	3·27	3,610	
1·0...	9·24½	1·37	2 4	2·03	2 03	2,241	
0·5...	9·51	2 08	1·5	1·86	0·93	...	Eccentric.
·25...	10·37	2·77	·9	...	..	...	
0 ...	14·52	...	...	..	...	...	

NOTE.—Mean $\frac{K}{A} = \frac{1}{5}$ (2·23 + 2 32 + 2·35 + 2·18 + 2·03) = 2·22.

1½″ of sand found in the well.

TABLE 3—(*Continued*).

Recuperation Test No. 8.

Date, 23rd June 1912.

NEW WELL No. 1.

Diameter = 15 feet.

Area (A) = 176·71 sq. ft.

$$\frac{K}{A}T = \log\frac{H}{h}.$$

H = 5′.

h.	Timings.	$\log\frac{H}{h}$.	$h(1+\log\frac{H}{h})$	$\frac{K}{A}$.	V.	Yield per hour in gallons.	Remarks.
H = 5′ ...	7·51′·40″	...	...	...	...	...	
4·5...	7·54′·18″	·11	5	2·50	11·25	12,420	
4·0...	7·57′·35″	·22	4·9	2·23	8·92	9,848	Eccentric.
3·5...	8· 1′· 5″	·36	4·8	2·29	8·02	8,854	
3·0...	8· 5′·18″	·51	4·5	2·24	6·72	7,419	
2·5...	8·10′·35″	·69	4·2	2·19	5·48	6,050	Eccentric.
2·0...	8·16′·50″	·92	3·8	2·19	4·38	4,836	
1·5...	8·25′·50″	1·20	3·3	2·11	3·17	3,500	
1·0...	8·38′·25″	1·61	2·6	2·07	2·07	2,285	
0·5...	9· 7′·10″	2·30	1·7	1·83	0·92	1,016	Eccentric.
0...	...	...	...	...	...	...	

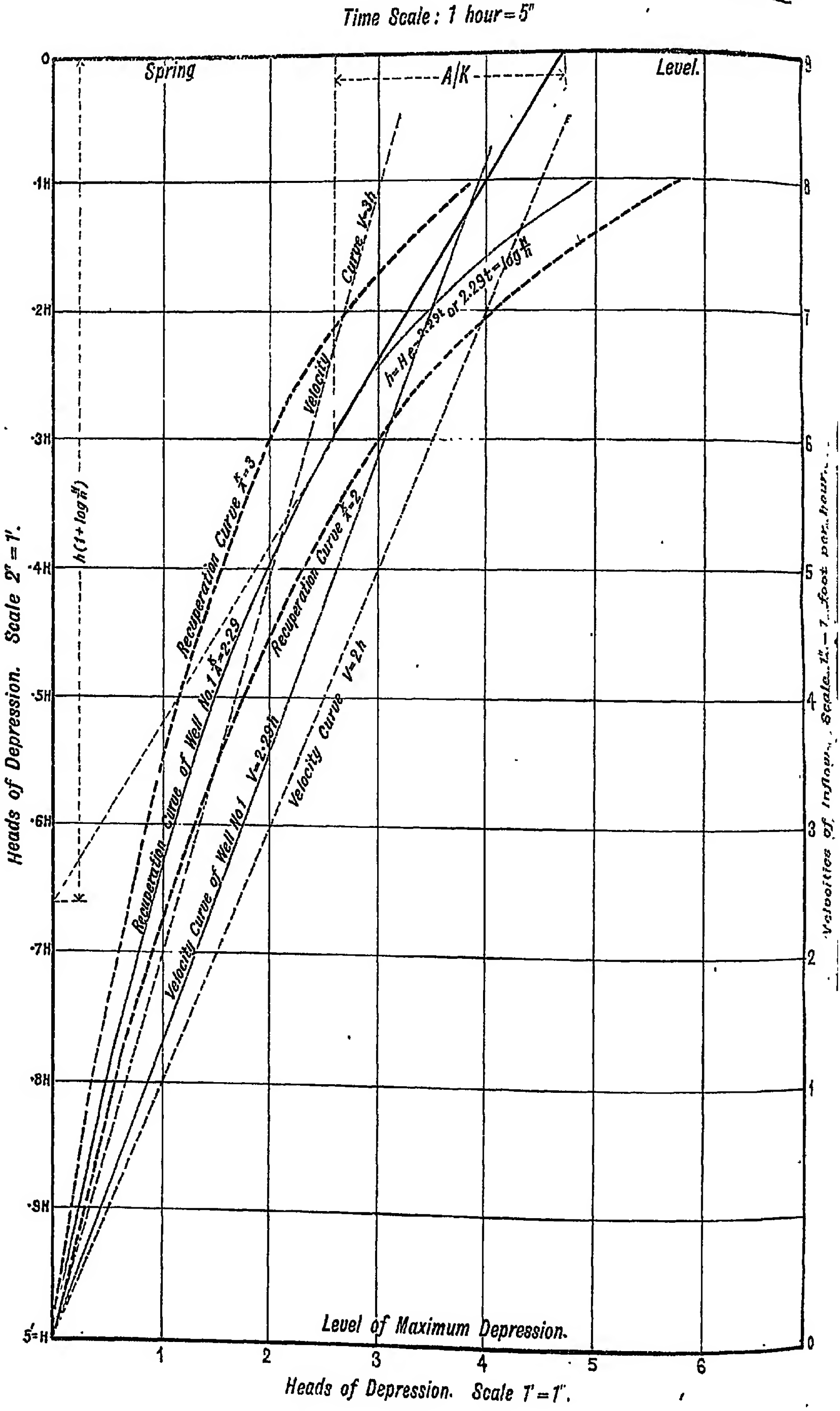
NOTE.—Mean $\frac{K}{A} = \frac{1}{6}$ (2·50 + 2·29 + 2·21 + 2·19 + 2·11 + 2·67) = 2·23.

This test was carried out after 12 endurance tests (Table 5) to ascertain if the co-efficient $\frac{K}{A}$, had fallen off a reference to the previous tests will show that the result is very satisfactory

The timings were taken with a stop watch.

RULING CURVES. WELL No. 1.

Plate D.



The dotted Curves on this plate are theoretical.

[signature] 2/7/12

TABLE 3—(*Continued*).

Ruling Curves.

WELL No. 1.

Diameter = 15 feet.

Area (A) = 176·71 sq. ft.

Recuperation Curve—$2{\cdot}29\ t = \log \frac{H}{h}$.

Velocity Curve—$V = 2{\cdot}29\ h$.

$H = 5'$.

h.	Timings in hours.	$\log \frac{H}{h}$	$h\left(1 + \log \frac{H}{h}\right)$.	$\frac{K}{A}$.	V.	Yield per hour in gallons.	Remarks
H = 5′ ...	...	...	...	...	11·45	12,641	
·9 H ...	·05	·11	5	..	10·31	11,382	
·8 H ...	·10	·22	4·9	...	9 16	10,113	
·7 H ...	·16	·36	4·8	...	8·02	8,854	
·6 H ...	·22	·51	1·5	...	6·87	7,585	
·5 H ...	·30	·69	1·2	$\frac{K}{A} = 2{\cdot}29$	5·73	6,326	
·4 H ...	·40	·92	3·8	...	4·58	5,056	
·3 H ...	·52	1·20	3·3	...	3·44	3,798	
·2 H ...	·70	1·61	2·6	..	2·29	2,528	
·1 H ...	1·00	2·30	1·7	...	1·15	1,270	
·0 ...	...	...	...	...	...	...	

NOTE.—Mean $\frac{K}{A} = \frac{1}{8}$ (2·36 + 2·07 + 2·38 + 2·35 + 2·49 + 2·21 + 2·22 + 2·23) = 2·29.

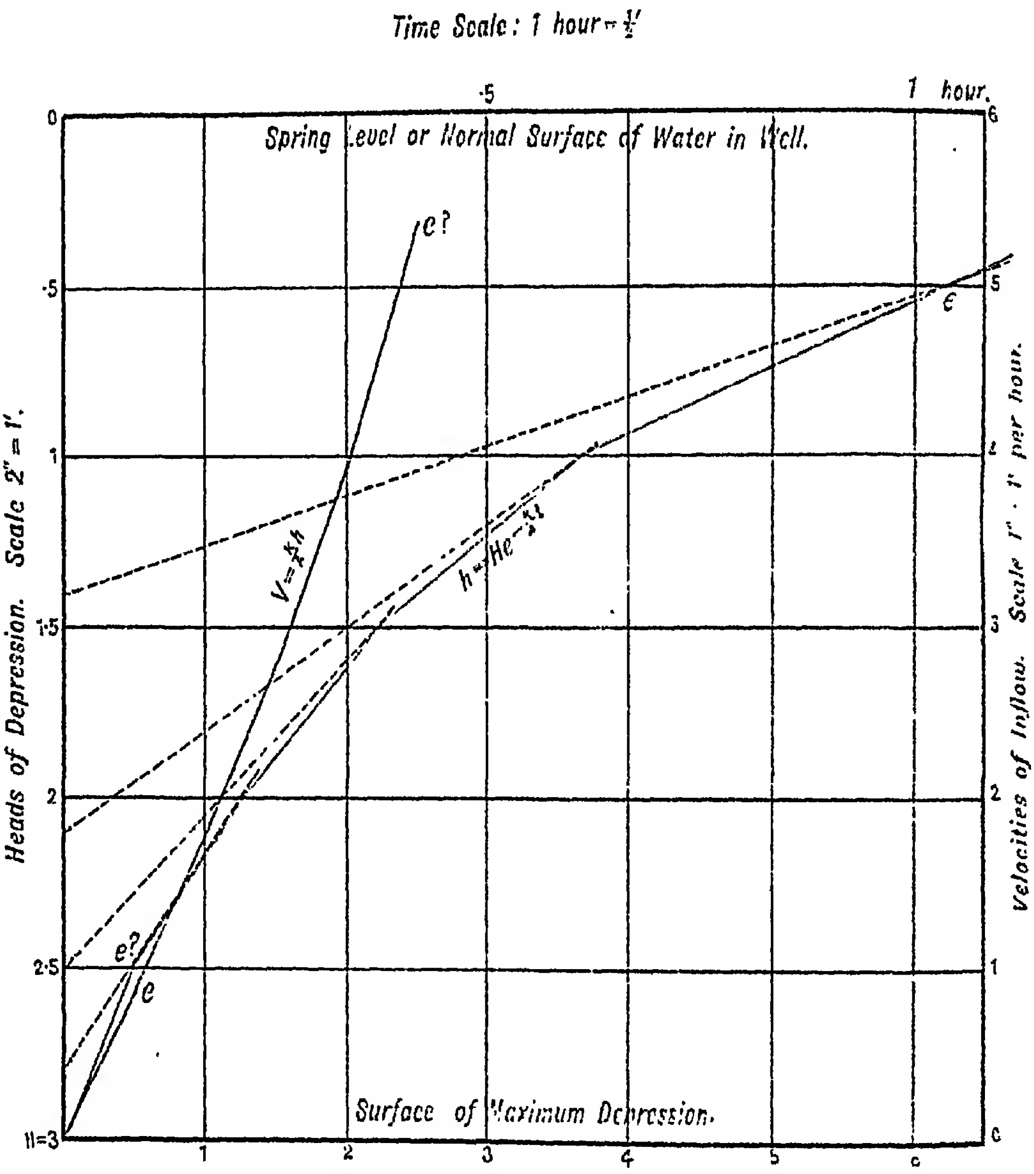
TABLE 3—(Concluded).

Recuperation Curve.

$$\frac{K}{\lambda} T = \log \frac{H}{h}.$$

h.	$\log \frac{H}{h}$	T: $\frac{K}{\lambda} = \frac{1}{2}$.	T: $\frac{K}{\lambda} = 1$.	T: $\frac{K}{\lambda} = 2$.	T: $\frac{K}{\lambda} = 3$.
0·1 H ...	2·30	1·60	2·30	1·15	0·77
0·2 H ...	1·61	3·20	1·61	0·81	0·54
0·3 H ...	1·20	2·40	1·20	0·60	0·40
0·4 H ...	0·92	1·84	0·92	0·46	0·31
0·5 H ...	0·69	1·38	0·69	0·35	0·23
0·6 H ...	0·51	1·02	0·51	0·26	0·17
0·7 H ...	0·36	0·72	0·36	0·18	0·12
0·8 H ...	0·22	0·44	0·22	0·11	0·07
0·9 H ...	0·11	0·22	0·11	0·06	0·04

TEST No. 1. WELL No. 2.



Heads of Depression. Scale 1" = 1'.

h. Cantin
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TABLE 4.

Recuperation Test No. 1.

Date, 15th June 1912.

New Well No. 2.

Diameter = 15 feet.

Area (A) = 176·71 sq. ft.

$$\frac{K}{A}T = \log\frac{H}{h}.$$

H = 3′.

h.	Timings.	$\log\frac{H}{h}$.	$h\left(1+\log\frac{H}{h}\right)$.	$\frac{K}{A}\left(=\frac{H}{h}\right)$.	V.	Yield per hour in gallons.	Remarks.
3′ ...	7.59	...	...	...	...	...	
2·5 ...	8·4	0·18	3	2·16	5 40	5,962	Doubtful.
2·0 ...	8·11½	0·41	2·8	1·97	3·94	4,350	
1·5 ...	8.21¼	0·69	2·5	1·86	2 79	3,080	
1·0 ...	8·35½	1·10	2·1	1·81	1 81	1,998	
0·5 ...	9·1	1·79	1·4	1·73	0·87	960	Eccentric.
0·0 ...	11·3	...	...	...	...	...	

Note.—Mean $\frac{K}{A} = \frac{1}{3}(1·97 + 1·86 + 1·81) = 1·88$.

TABLE 4—(*Continued*).

Recuperation Test No. 2.

Date, 16th June 1912.

NEW WELL NO. 2.

Diameter = 15 feet.

Area (A) = 176·71 sq. ft.

$$\frac{K}{A}T = \log\frac{H}{h}.$$

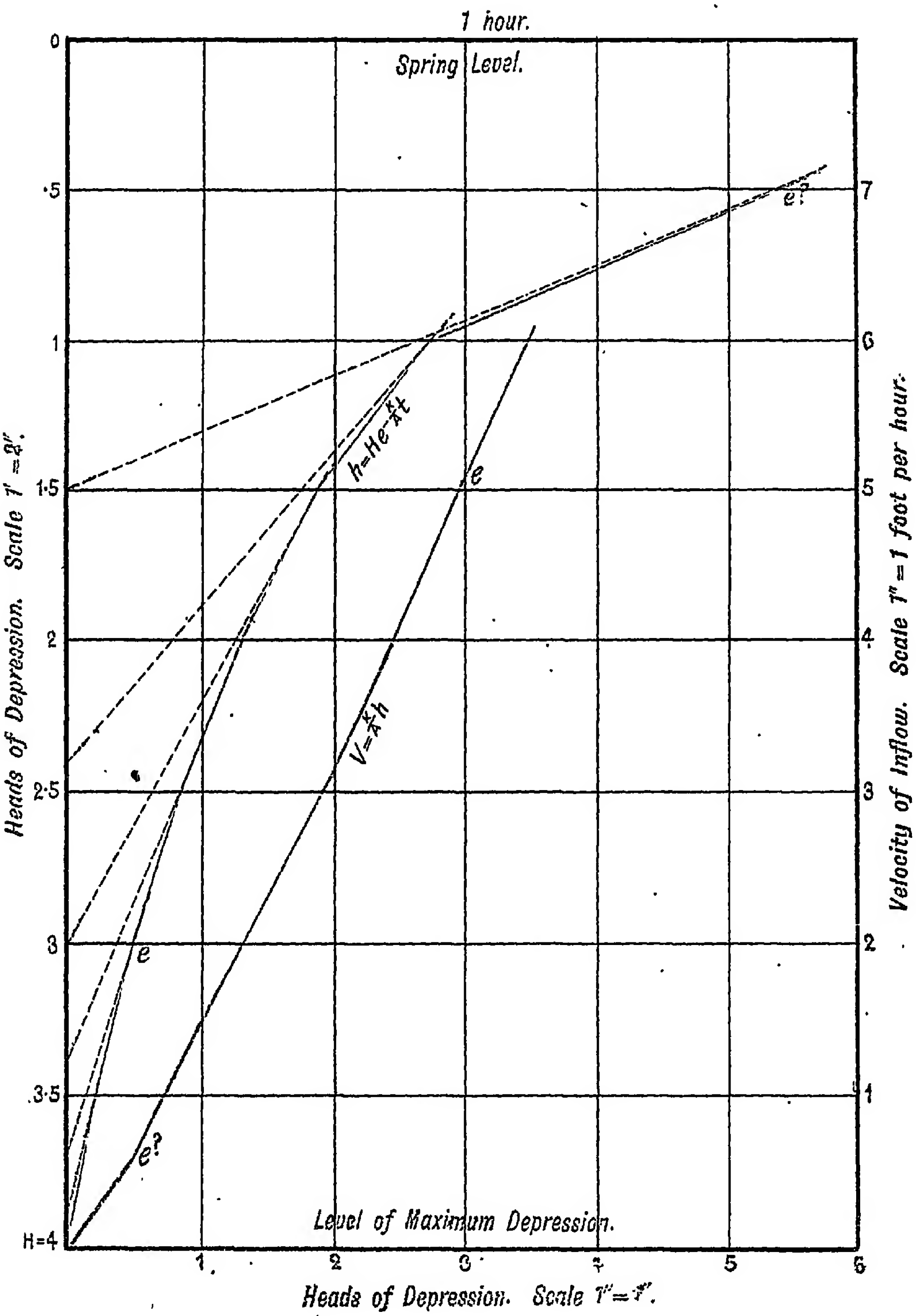
$H = 4'$.

h.		Timings	$\log\frac{H}{h}$	$h\left(1+\log\frac{H}{h}\right)$	$\frac{K}{A}$ ([illegible]).	V.	Yield per hour in gallons.	Remarks.
4′	...	12·30½	...	...	...	...	...	
3·5	...	12·35	0·13	4·0	1·73	6·05	6,682	
3·0	...	12·40¾	0·29	3·9	1·70	5·10	5,633	Eccentric.
2	.	12·47¾	0·47	3·7	1·64	4·10	4,528	
2·0	...	12·57¼	0·69	3·4	1·55	3·10	3,424	
1·5	...	13·9	0·98	3·0	1·52	2·28	2,518	
1·0	...	13·26½	1·37	2·4	1·47	1·47	1,623	
0·5	...	14·19	2·08	1·5	1·15	0·58	640	Doubtful.
0·0	...	3·30	...	...	..	...	...	

NOTE.—Mean $\frac{K}{A} = \frac{1}{5}(1·73 + 1·61 + 1·55 + 1·52 + 1·47) = 1·58$

TEST No. 2. WELL No. 2.

Time Scale: 1 hour = 3".



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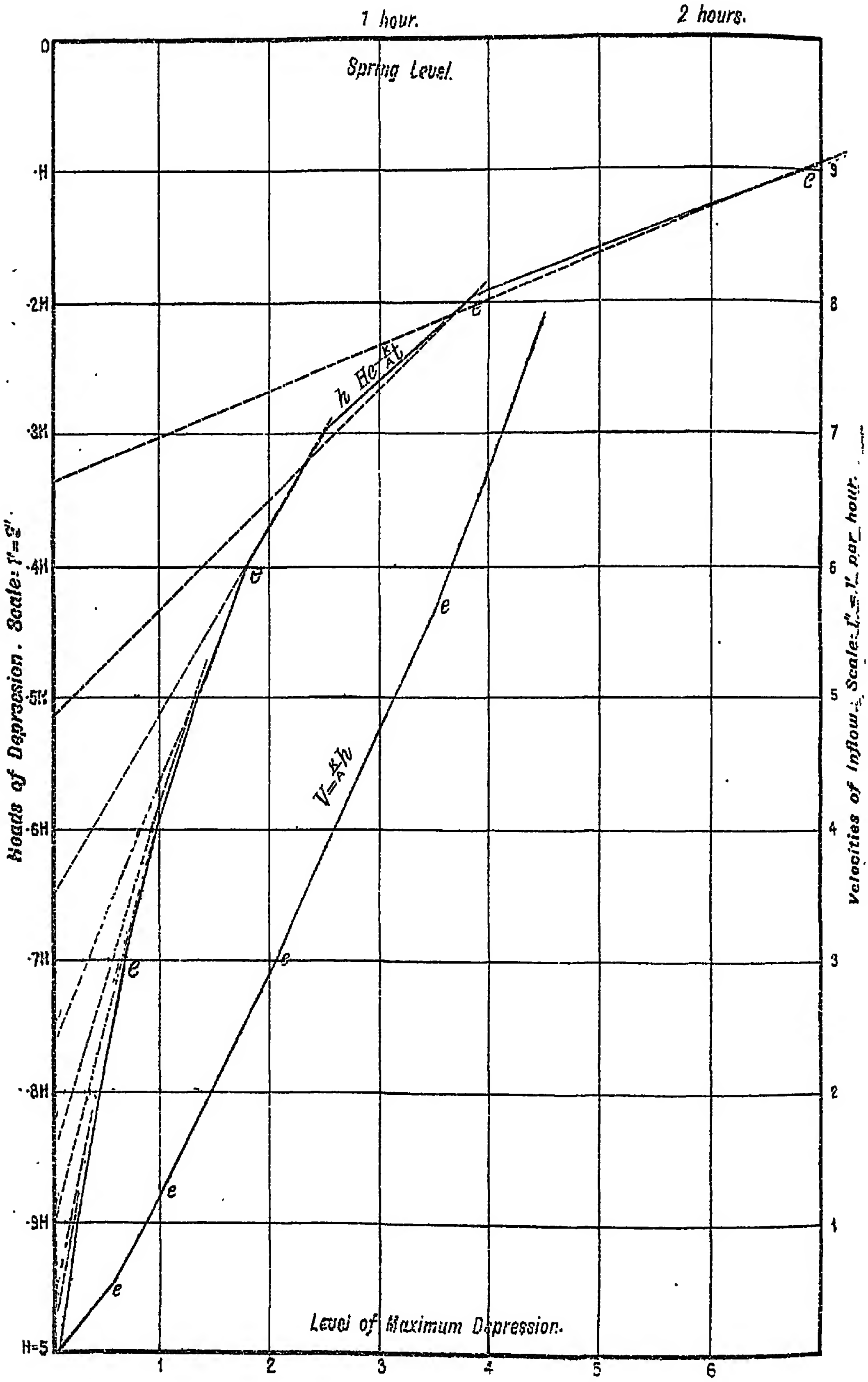
TEST No. 3. WELL No. 2.

Time Scale: 1 hour = 3".



Heads of Depression. Scale: 1" = 1'

[signature]
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TABLE 4 —(*Continued*).

Recuperation Test No. 3.

Date, 17th June 1912.

NEW WELL No. 2.

Diameter = 15 feet.

Area (A) = 176·71 sq. ft.

$$\frac{K}{A} T = \log \frac{H}{h}.$$

H = 5′.

h.	Timings.	$\log \frac{H}{h}$.	$h\left(1+\log \frac{H}{h}\right)$.	$\frac{K}{A}\left(=\frac{V}{h}\right)$.	V.	Yield per hour in gallons.	Remarks.
H=5′ ...	9·14½	...	...	...	...	...	
·9 H ...	9·18¼	0·11	5·0	1·76	7·92	8,747	
·8 H ...	9·22¼	0·22	4·9	1 70	6·80	7,510	
·7 H ...	9·27½	0·36	4·8	1·63	5 70	6,293	Eccentric.
·6 H ...	9·33½	0·51	4·5	1 61	4·83	5,334	
·5 H ...	9·41	0·69	4·2	1·56	3·90	4,307	
·4 H ...	9·51½	0·92	3·8	1·50	3·00	3,313	Eccentric.
·3 H ...	10·4½	1·20	3·3	1·44	2·16	2,385	
·2 H ...	10·31¼	1·61	2·6	1·26	1·26	1,391	Eccentric.
·1 H ..	11·33	2·30	1·7	1·00	·5	552	Eccentric.
·25 H ...	13·48	...	...	...	...	...	
0·0 ...	0·30	...	...	...	...	...	

NOTE.—Mean $\frac{K}{A} = \frac{1}{5}$ (1·76 + 1·70 + 1·61 + 1·56 + 1·44) = 1·61.

TABLE 4—(*Continued*).

Recuperation Test No. 4.

Date, 17th June 1912.

NEW WELL NO. 2.

Diameter =15 feet.

Area (A)=176·71 sq. ft.

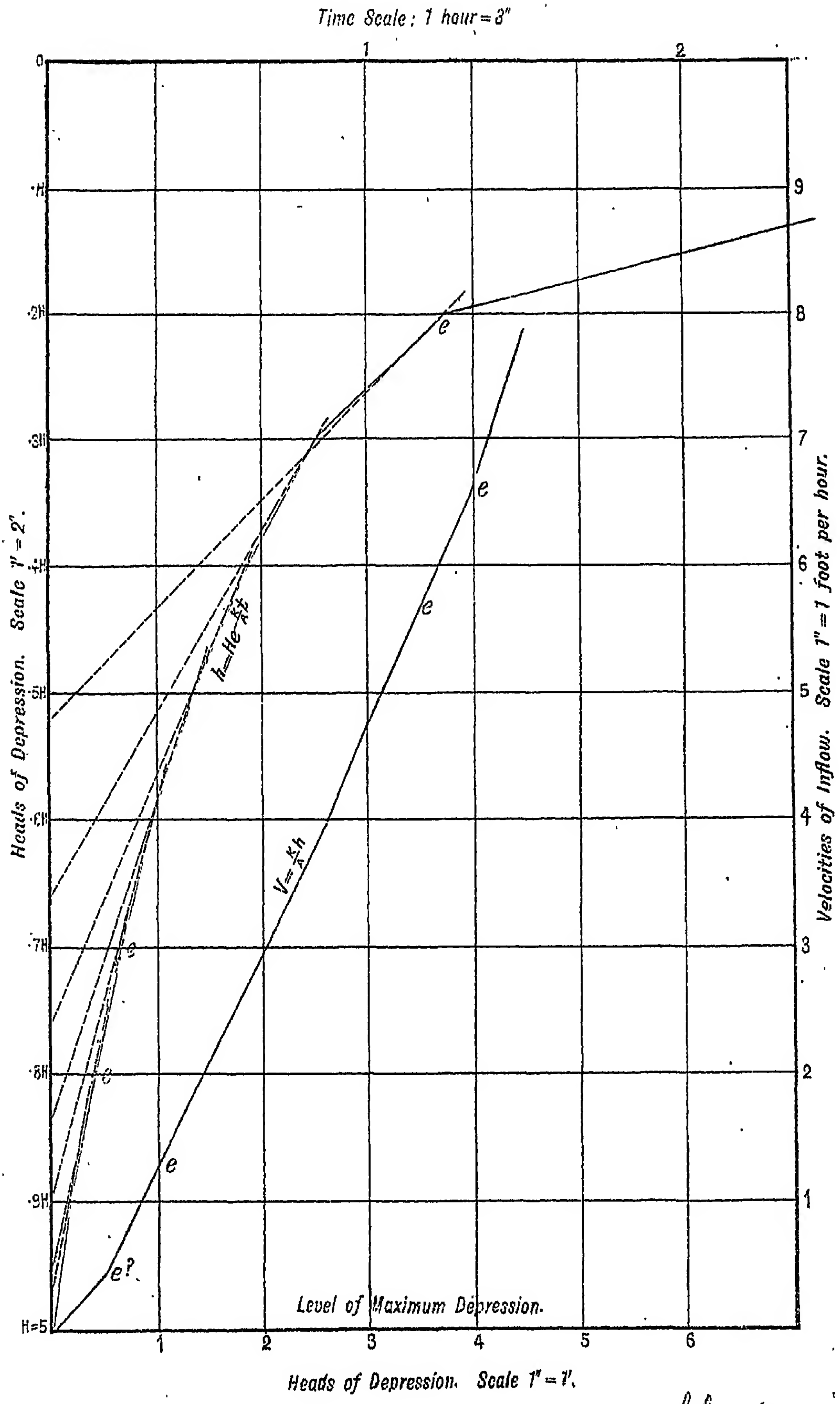
$$\frac{K}{A} T = \log \frac{H}{h}.$$

H=5′.

h.	Timings.	$\log \frac{H}{h}$.	$h\left(1+\log \frac{H}{h}\right)$.	$\frac{K}{A}\left(=\frac{V}{h}\right)$.	V.	Yield per hour in gallons.	Remarks.
H=5′ ...	8·26½	..	..	...	...	..	
·9 H ...	8·30¼	·11	5·00	1·76	7·92	8,747	
·8 H	8·34½	·22	4·9	1·65	6·60	7,289	Eccentric.
·7 H ...	8·39¾	·36	4·8	1·63	5·71	6,306	Eccentric.
·6 H ...	8·45¾	·51	4·5	1·60	4·80	5,301	
·5 H ...	8·53½	·69	4·2	1·53	3·83	4,230	
·4 H ...	9·3 ¾	·92	3·8	1·48	2·96	3,269	
·3 H ...	9·16¾	1·20	3·3	1·43	2·15	2,374	
·2 H ...	9·41	1·61	2·6	1·30	1·30	1,436	Eccentric.
·1 H ...	10·58	2·30	1·7	0·91	0·45	497	Doubtful.
·05H ...	13·24	...	...	...	..	...	
0·0 ...	...	...	...	..	...	...	

NOTE.—Mean $\frac{K}{A} = \frac{1}{5}$ (1·76+1·60+1·53+1·48+1·43)=1·56.

TEST No. 4.



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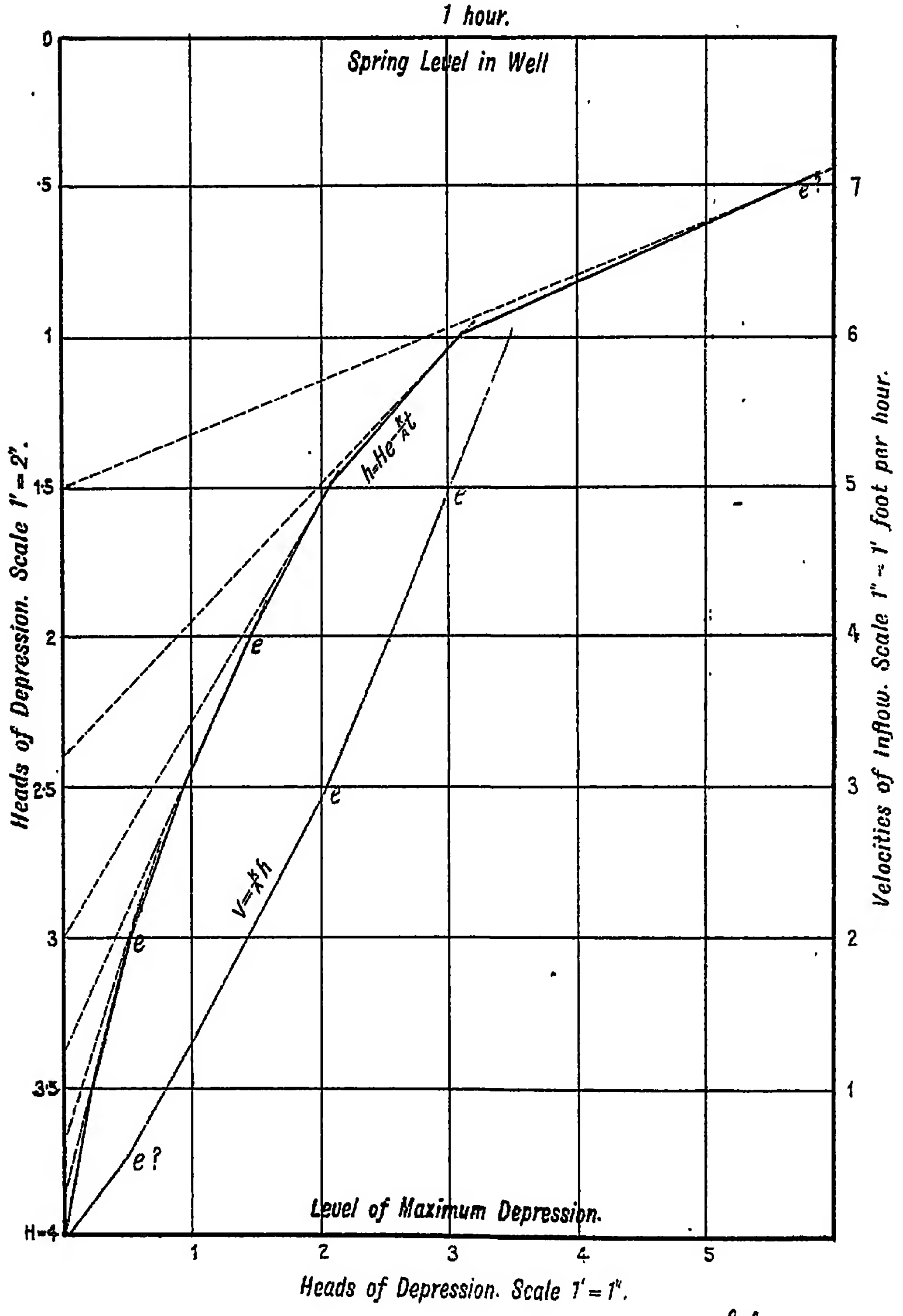
TEST No. 5. WELL No. 2.

Time Scale: 1 hour = 3".



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1/8/12

TABLE 4—(*Continued*).

Recuperation Test No. 5.

Date, 20th June 1912.

NEW WELL No. 2.

Diameter = 15 feet.

Area (A) = 176·71 sq. ft.

$$\frac{K}{A} T = \log \frac{H}{h}.$$

H = 4′.

h.	Timings.	$\log \frac{H}{h}$.	$h\left(1 + \log \frac{H}{h}\right)$	$\frac{K}{A}\left(= \frac{V}{h}\right)$	V.	Yield per hour in gallons.	Remarks.
4′ ...	8·41	...	......	...	...	...	
3·5 ...	8·45½	·13	4·0	1·73	6·05	6,682	
3·0 ...	8·51½	·29	3·9	1·66	4·98	5,500	Eccentric.
2·5 ...	8·59	·47	3·7	1·57	3·92	4,329	
2·0 ...	9 9 ½	·69	3·4	1 45	2·90	3,203	Eccentric.
1·5 ...	9·22	·98	3·0	1·43	2·14	2,363	
1·0 ...	9·42½	1·38	2·4	1·34	1·34	1,480	
0·5 ...	10·34	2·08	1·5	1·10	·55	629	Doubtful.
0·0 ...	17·50	...	......	...	...	...	

NOTE.—Mean $\frac{K}{A}$ = ¼ (1·73 + 1·57 + 1·43 + 1·34) = 1·52.

TABLE 4—(*Continued*).

Recuperation Test No. 6.

Date, 21st June 1912.

NEW WELL No. 2.

Diameter = 15 feet.

Area (A) = 176·71 sq. ft.

$$\frac{K}{A} T = \log \frac{H}{h}.$$

H = 3′.

h.	Timings.	$\log \frac{H}{h}$.	$h\left(1+\log \frac{H}{h}\right)$	$\frac{K}{A}\left(=\frac{V}{h}\right)$	V.	Yield per hour in gallons.	Remarks
3′ ...	7·41½	...	......	...	...	...	
2·5 ...	7·47½	·18	3·0	1·80	4·50	4,969	Doubtful.
2·0 ...	7·54½	·41	2·8	1·90	3·80	4,197	
1·5 ...	8·6	·69	2·5	1·69	2·54	2,805	
1·0 ...	8·20½	1·10	2·1	1·69	1·69	1,866	
0·5 ...	9·2 ½	1·79	1·4	1·33	·67	740	
·25 ...	9·47½	...	......	...	...	...	
0·0 ...	13·15	...	......	...	...	...	

NOTE.—Mean $\frac{K}{A} = \frac{1}{4}$ (1·90 + 1·69 + 1·69 + 1·33) = 1·65.

TEST No. 6. WELL No. 2.

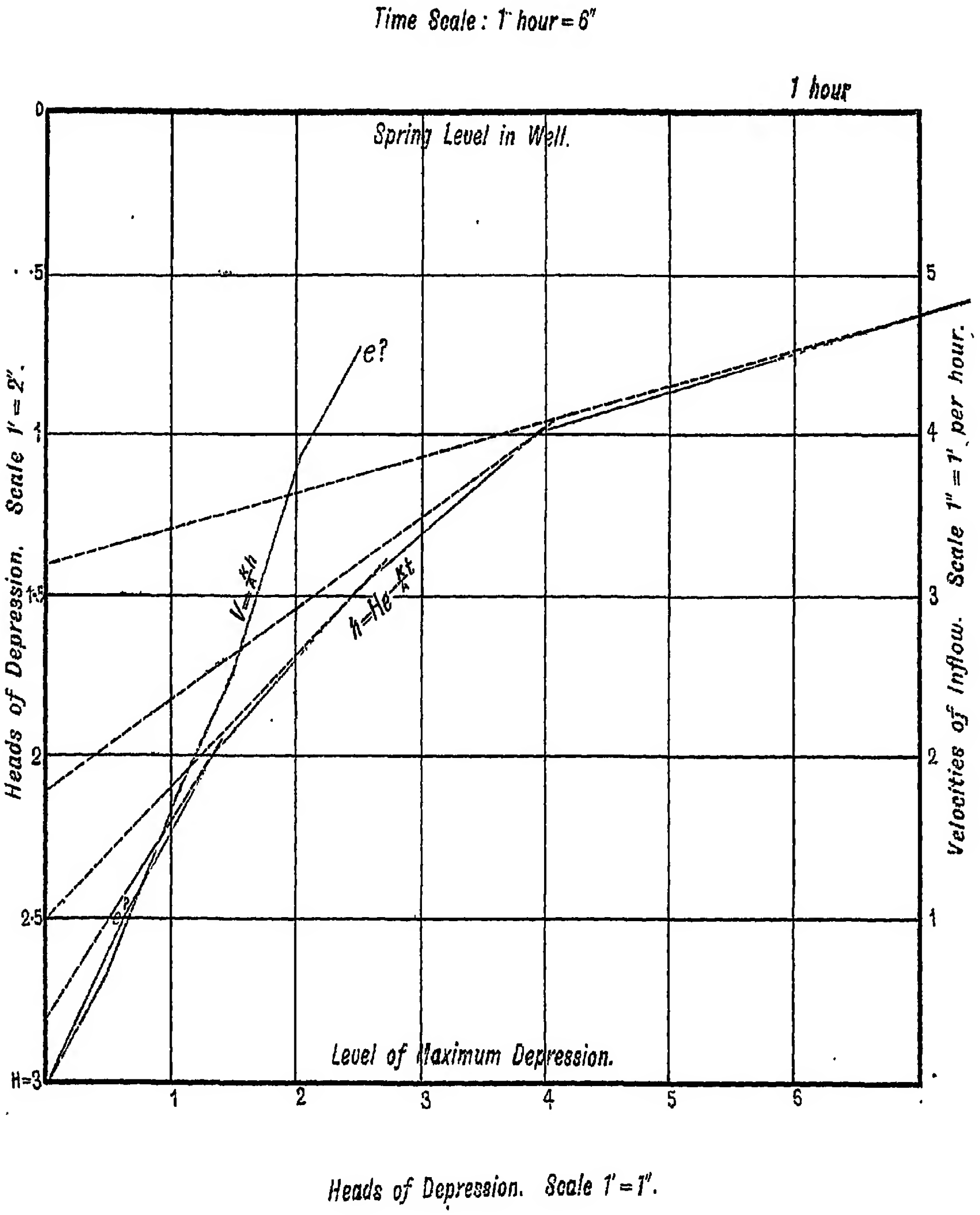

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TABLE 4—(*Concluded*).

Ruling Curves.

WELL No. 2.

Diameter = 15 feet.

Area (A) = 176·71 sq. ft.

Recupertion Curve $1{\cdot}63\,t = \log \frac{H}{h}$.

Velocity Curve :—$V = 1{\cdot}63\,h$.

$H = 5'$.

h.	Timing in hours.	$\log \frac{H}{h}$.	$h\left(1 + \log \frac{H}{h}\right)$.	$\frac{K}{A}$.	V.	Yield per hour in gallons.	Remarks.
H = 5′ ...	...	...	......	...	8·15	9,000	
·9 H ...	·07	·11	5·	...	7·33	8,092	
·8 H ...	·14	·22	4·9	...	6·52	7,198	
·7 H ...	·22	·36	4·8	...	5·71	6,304	
·6 H ...	·31	·51	4·5	...	4·89	5,398	
·5 H ...	·42	·69	4·2	$\frac{K}{A} = 1{\cdot}63$	4·08	4,504	
·4 H ...	·56	·92	3·8	...	3·26	3,599	
·3 H ..	·74	1·20	3·3	...	2·45	2,705	
·2 H ...	·99	1·61	2·6	...	1·63	1,799	
·1 H ...	1·41	2·30	1·7	...	0·82	905	
0 ...	...	...	......	...	...	...	

NOTE.—Mean $\frac{K}{A} = \frac{1}{7}$ (1·88 + 1·58 + 1·61 + 1·56 + 152 + 1·65 + 1·64) = 1·63.

RULING CURVES. WELL No. 2.

Plate D.

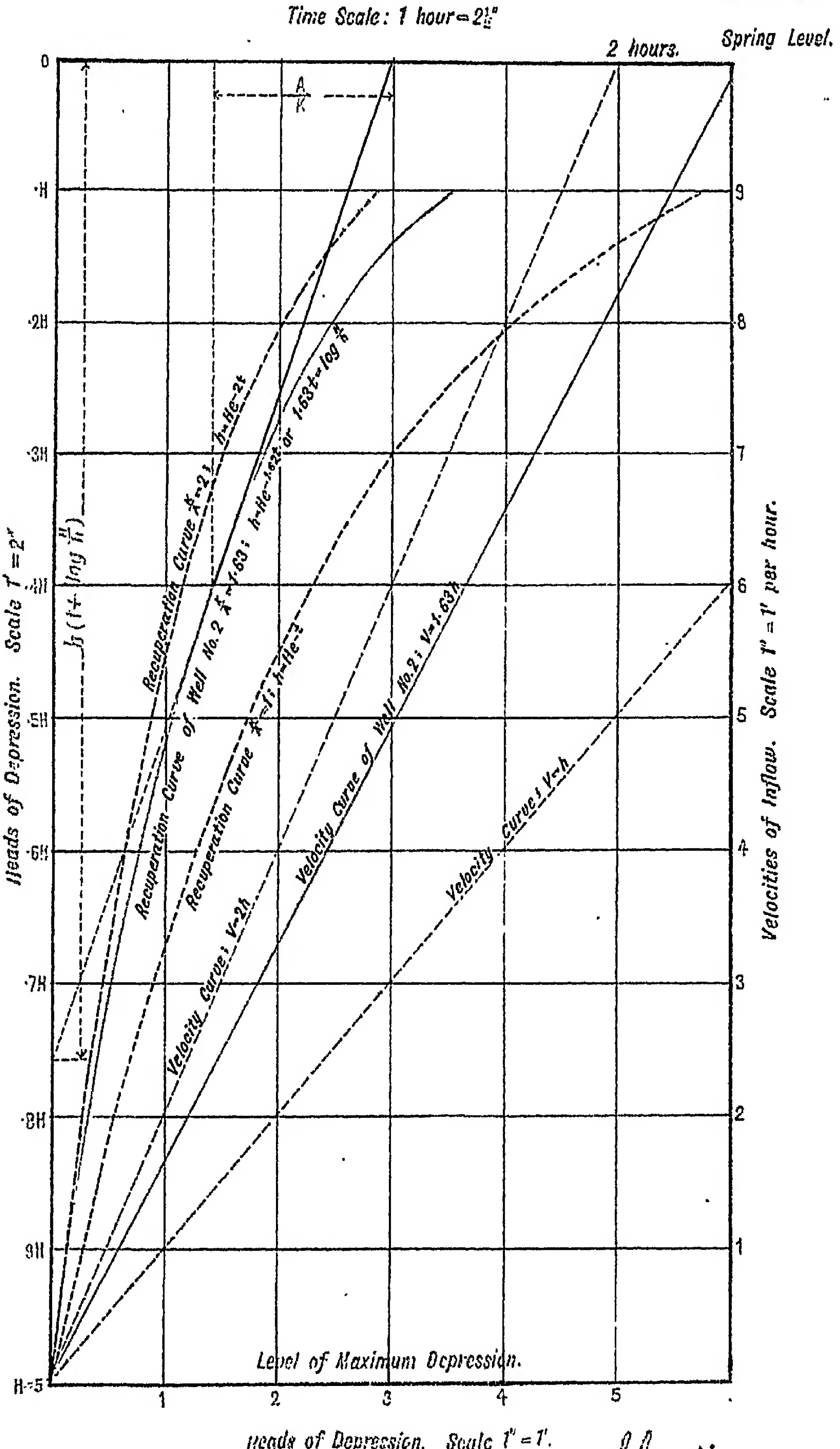

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TABLE 5.

Endurance Tests.

Date.	Average head.		Duration of test in hours.		Yield in gallons.		Total Yield in gallons.
	Well No. 1.	Well No. 2.	Well No. 1.	Well No. 2.	Well No. 1.	Well No. 2.	
9-6-12 ...	3	...	16	...	112,000		
10-6-12 ...	3	...	16	...	105,500		
11-6-12 ...	3	...	16	...	110,200		
12-6-12 ...	3½	...	16	...	121,850		
13-6-12 ...	3	...	16	...	113,200		
14-6-12 ...	3½	...	16	..	120,500		
15-6-12 ...	3	...	16	...	105,400		
16-6-12 ...	3	...	16	...	105,250		
17-6-12 ...	3½	...	16	...	122,400		
18-6-12 ...	2½	...	16	...	92,700		
19-6-12 ...	3	...	16	...	104,900		
20-6-12 ...	...	...	No.	Test.	...		
21-6-12 ...	...	...	No.	Test.	..		
22-6-12 ...	3¾	*3½*	9	*16*	76,100	*97,900*	174,000
23-6-12 ...	3½	*3½*	12	*16*	106,000	*94,300*	200,300
24-6-12 ...	4.	*4*	16	*16*	146,300	*105,960*	252,260
25-6-12 ...	4	*3¾*	16	*16*	150,400	*104,800*	255,200
26-6-12 ...	4	*4*	16	*16*	152,400	*105,800*	258,200
27-6-12 ...	4	*4*	16	*11*	150,300	*71,900*	222,200
28-6-12 ...	4	*4*	16	*16*	146,600	*100,200*	246,800
29-6-12 ...	4	*4*	16	*16*	151,000	*96,200*	247,200
30-6-12 ...	3¼	*4*	14	*14*	94,800	*84,500*	179,300
1-7-12 ...	...	...	No.	Test.	..	...	...
2-7-12 ...	4	*4*	16	*16*	131,250	*98,800*	230,050
3-7 12 ...	3	*3*	16	*16*	104,200	*85,250*	189,450

TABLE 5—(*Concluded*).

DATE.	AVERAGE HEAD.		DURATION OF TEST IN HOURS.		YIELD IN GALLONS.		TOTAL YIELD IN GALLONS.
	Well No. 1.	Well No. 2.	Well No. 1.	Well No 2.	Well No. 1.	Well No 2	
4-7-12 ...	3	*3*	16	*16*	102,200	*87,200*	189,400
5-7-12 ...	3	*3*	16	*16*	100,800	*79,200*	180,000
6-7-12 ...	3	*3*	16	*16*	102,900	*74,600*	177,500
7-7-12 ...	3	*3*	16	*16*	106,300	*80,200*	186,500
8-7-12 ...	3	*3*	16	*16*	104,700	*77,200*	181,900
9-7-12 ..	3	*3*	16	*16*	102,800	*83,500*	186,300
10-7-12 ...	3	*3*	16	*16*	102,200	*80,200*	182,400
11-7 12 ...	3	*3*	16	*16*	104,400	*80,800*	185,200
12-7-12 ...	3	*3*	16	*16*	102,900	*82,400*	185,300
13-7-12 ...	3	*3*	16	*16*	103,500	*81,300*	184,800
14-7-12 ...	3	*3*	16	*16*	105,000	*85,500*	190,500
15-7-12 ...	3	*3*	16	*16*	104,000	*81,150*	185,150
16-7-12 ...	3	*3*	16	*16*	101,600	*82,700*	184,300
17-7-12 ...	...	...	No.	Test.	...	...	...
18-7-12 ...	4	*4*	12	*12*	116,400	*82,050*	198,450
19-7-12 ...	4	*4*	12	*12*	112,700	*83,350*	196,050
20-7-12 ...	4	*4*	12	*12*	116,300	*83,750*	200,050
21-7-12 ...	4	*4*	12	*12*	115,700	*81,600*	197,300
22-7-12 ...	4	*4*	12	*12*	115,500	*81,300*	196,800
23-7-12 ...	4	*4*	12	*12*	111,100	*84,600*	195,700
24-7-12 ...	4	*4*	16	*16*	148,800	*108,350*	257,150
25-7-12 ...	...	...	No.	Test.	...	..	...
26-7-12 ...	4	*4*	16	*16*	144,600	*104,300*	248,900
27-7-12 ...	...	...	No	Test.	...	...	...
28-7-12 ...	4	*4*	16	*16*	145,200	*104,500*	249,700
29-7-12 ...			Tests	Stopped			

PLATE E.

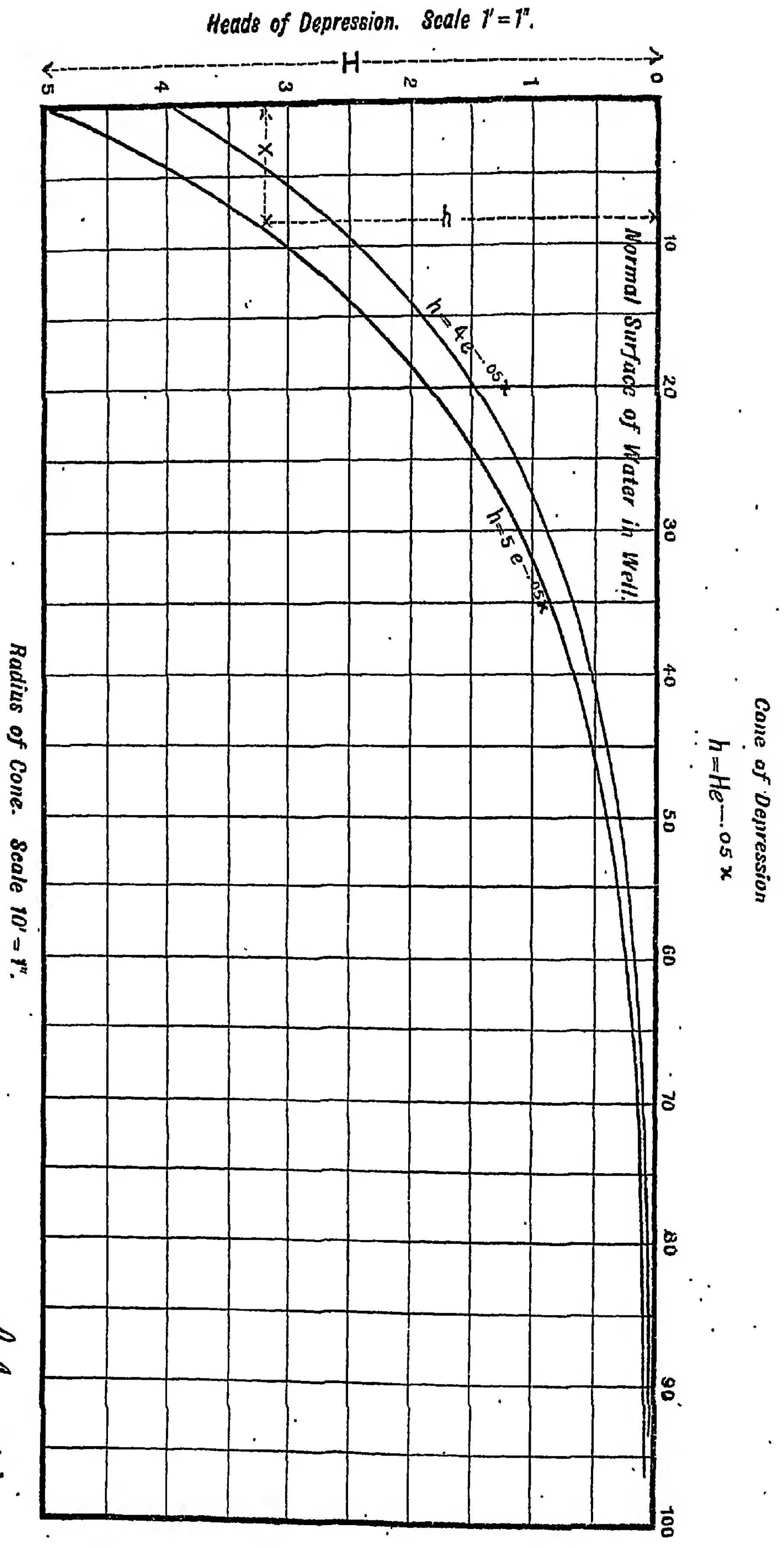

Heads of Depression. Scale 1' = 1".
H
0
1
2
3
4
5
h
x
Normal Surface of Water in Well.
h=4e^-.05x
h=5 e^-.05x
Cone of Depression
h=He^-.05x
Radius of Cone. Scale 10' = 1".
10
20
30
40
50
60
70
80
90
100

TABLE 6.

Cone of Depression.

$$h = H\ e^{-m\,x}$$

or

$$m\,x = \log_e \frac{H}{h}.$$

Date.		H.	h.	Mean h.	m.	Remarks.
22-6-12 ...	...	$3\frac{3}{4}'$	10″			
23-6-12 ...	...	$3\frac{1}{2}'$	$8\frac{1}{2}''$			
25-6-12 ...	...	$3\frac{3}{4}'$	9″			
26-6-12 ...	...	4′	9″			
29-6-12 ...	...	4′	9″	= 9″	·05	
30-6-12 ...	...	4′	9″			
2-7-12 ...	...	4′	9″			
3-7-12 ...	...	3′	8″			
4-7-12 ...	...	3′	8″			
6-7-12 ...	...	3′	7″			
8-7-12 ...	...	3′	10″			
9-7-12 ...	...	3′	9″			
11-7-12 ...	...	3′	9″	= 7·8″	·04	
12-7-12 ...	...	3′	9″			
13-7-12 ...	...	3′	6″			
14-7-12	.	3′	6″			
15-7-12 ...	...	3′	6″			

TABLE 6—(*Continued*).

Date.		H	h.	Mean h.	m.	Remarks.
18-7-12 ...	...	4′	12″			
19-7-12 ...	...	4′	9″			
20-7-12 ...	...	4′	9″			
21-7-12 ...	...	4′	9″			
22-7-12 ...	...	4′	9″	= 10″	·05	Average m = ·05
23-7-12 ...	...	4′	$9\frac{1}{2}$″			Equation of Cone is.
24-7-12 ...	...	4′	$10\frac{1}{2}$″			$h = H e^{-\cdot 05 x}$.
26-7-12 ...	...	4′	11″			
28-7-12 ...	...	4′	11″			

TABLE 6—(*Concluded*).

Cone of Depression.

$$h = H e^{-\cdot 05\, x}$$

or

$$x = 20 \log \frac{H}{h}.$$

$$H = 5'.$$

h.	$\log \frac{H}{h}$.	X.	Remarks.
Q	......	∞	
H	2·30	46·0	
·2 H	1·61	32·2	
·3 H	1·20	24·0	
·4 H	0·92	18·4	
·5 H	0·69	13·8	
·6 H	0·51	10·2	
·7 H	0·36	7·2	
·8 H	0·22	4·4	
·9 H	0·11	2·2	
H	0	0	

AMENDED ESTIMATE

OF THE COST OF THE

SAGARMATI WATER WORKS SCHEME FOR AJMER.

1913.

HEAD WORKS—COST OF ONE WELL.

DETAILS.

Serial Number and Name of Sub-head and details of Work.	Dimensions.				Numbers, Contents or Area.	Total.	Grand Total.
	Number.	Length.	Breadth.	Height or Depth.			
ONE WELL.							
(1) Dry excavation well 19′ diameter ...	1	283·5	...	8	2,288	...	
Chamber	1	10·25	6·5	9·0	600	...	
"	2	3·0	6·5	9·0	351	...	3,239
(2) Sinking from 8′ to 13′.	...	5	...	...	...	...	5′
(3) Sinking from 13′ to 18′.	...	...	...	...	...	...	5′
(4) Sinking from 18′ to 23′.	...	...	...	...	...	...	5′
(5) Sinking from 23′ to 25′.	...	...	...	...	...	...	2′
(6) Rubble masonry in lime							
Steining	1	53·4	2	27	...	2,884	
Chamber	1	21·5	1·25	11	...	296	
"	2	3⅜	1·25	11	...	93	
						3,273	
Deduct arch	...	...	...	...	...	10	3,263
(7) Arch work round pipe.	1	4·9	...	2	...	...	10

HEAD WORKS—COST OF ONE WELL—(*Continued*).

Serial Number and Name of Sub-head and details of Work.	Dimensions. Number.	Length.	Breadth.	Height or Depth.	Numbers, Contents or Area.	Total.	Grand Total.
(8) Concrete—							
Under chamber ..	...	10·25	7·5	1	77	...	...
" ...	...	4·0	6·5	1	26	...	103
(9) Stone slabs—							
Coping round chamber.	...	15·5	$1\frac{1}{4}$	...	19	...	...
" " ...	2	$3\frac{3}{8}$	$1\frac{1}{4}$	...	8	...	...
Floor of chamber ...	1	7·0	3·25	...	23	...	...
" " ...	1	4·75	3·25	...	16	...	...
Resting plates for valve.	1	1	1	...	1	...	...
Resting plates for breaking iron ...	1	1	1	...	1	...	...
Bed plates for beams	4	2	2	...	16	...	...
Corbelling over beams	2	14	1	...	28	...	...
Trap door	1	5	2·5	...	13	...	125
(10) Roofing—							
Over well $20\frac{1}{2}$ diameter.	...	...	...	...	330	...	330
(11) Steel beams 9″ × 4″ @ 21 lbs.	2	16	@21	...	...	...	6 cwt.

HEAD WORKS–COST OF ONE WELL—(*Continued*).

Serial Number and Name of Sub-head and details of Work.	Dimensions.				Numbers, Contents or Area.	Total.	Grand Total.
	Number.	Length.	Breadth.	Height or Depth.			
(12) Iron works suspension rods $\frac{3}{4}''$ ...	2	11·5	23	@1·47	...	33·8	
Clips to beams $2'' \times \frac{1}{2}''$ ...	4	1	4	...	...	...	
Carrier to pipe	1	$1\frac{1}{2}$	1·5	...	...	...	
			5·5	@3·34	...	18·4	
Ladder $1\frac{1}{4}''$ rod	31	4	124	4·09	...	507·2	
Trap door	2	5	10	...	...	...	
L $3'' \times 3'' \times \frac{3}{8}''$	2	3	6	...	...	...	
			16	7·03	...	112·5	
Gussets $\frac{3}{8}''$	$4 \times \frac{1}{2}$	$\frac{1}{2} \times \frac{1}{2}$	·5	15	...	7·5	
Nuts, etc.	10%	...	120	...	...	12·0	
Vertical tie bars 1" ...	8	12	96	2·62	...	251·5	
Flat tie bars $3'' \times \frac{1}{2}''$ ...	1	53·4	...	5	...	267	
Bolts and nuts for above...	16	...	...	1·5	...	24	
Breaking bars for pipe L $2 \times 2 \times \frac{1}{2}$	1	1	1	5·83	...	5·8	
						1,240	

HEAD WORKS—COST OF ONE WELL—(*Concluded*).

Serial Number and Name of Sub-head and details of Works.	Dimensions. Number.	Length.	Breadth.	Height or Depth.	Numbers, Contents or Area.	Total.	Grand Total.
CURBS L 3 × 3 × $\frac{3}{8}$—							
Horizontal beams ...	12	2	24	...	...	...	
Vertical stiffeners ...	12	15/12	16	...	...	...	
Sloping "	12	25/12	29	...	...	...	
Outer ring	1	...	60	...	...	...	
Inner "	1	...	11	...	...	...	
			170	7·03	...	1,195	
Cutting plate $\frac{1}{2}$" ...	60	$25\frac{3}{4}$/12	·129	20	...	2,580	
Gusset plate $\frac{1}{4}$	12 × $\frac{1}{2}$	7/4 × 7/4	16	10	...	160	
Sloping plate	34/12	534	151	10	...	1,510	
Overpieces, etc.	10%	5,445	...	...	...	545	
							7,230 = 65 cwt.
(13) Metalling around well	1	78·5	6	$\frac{1}{2}$	236	...	236 c.ft.
(14) Well sinking apparatus & tools ~~C. I. Bowl for Weepers~~	1	...	...	~~cwt. 55~~	...	...	~~11 cwt.~~
(15) Copper gauze for above	8	...	...	...	...	...	8 No.

SAGARMATI WATER WORKS—COST OF ONE WELL.

ABSTRACT.

Serial Sub-head No.	Quantity.	Denomination.	Sub-heads of Works.	Rate.	Per.	Estimated Cost.	European Stores.
				Rs		Rs.	
1	3,239	c.ft.	Dry excavation ...	8	‰	26	
2	5	l.ft.	Sinking 9′-13′	20	l.ft.	100	
3	5	„	„ 14′-18′	30	„	150	
4	5	„	„ 19′-23′	40	„	200	
5	2	„	„ 24′-25′	50	„	100	
6	3,263	c.ft.	Rubble masonry in lime	20	%	653	
7	10	„	Archwork	35	%	4	
8	103	„	Concrete	10	%	10	
9	125	s.ft.	Stone slabs	18	% s.ft.	22	
10	330	„	Roofing	30	% „	99	
11	6	cwt.	Steel beams	9	cwt.	54	
12	65	„	Iron work	20	md.	1,300	
13	236	c.ft.	Metalling consolidated	8	% c.ft.	19	
14	1 ~~49~~	each ~~cwt.~~	Well sinking apparatus & tools / Cast iron ~~boxes~~ ...	528 ~~12~~	each ~~cwt.~~	~~588~~ 528	
15	8	No.	Copper gauze strainers	5	each	40	
			Total cost of each Well ...			3,305	

ESTIMATE OF SUCTION MAIN.

DETAILS OF PIPING, Etc.

Well No. 1 (*also Well No. 8*)—

Taper, flanged 4″-5″	1
Bend, flanged 90°-5″	1
Straights, flanged 5″ nine feet	22
„ and spigot 5″ × 4½′	1*

Well No. 2 (*also Well No. 7*)—

T. piece, socket = 5″, flange = 6″ and T. end = 4″ flanged	1
Straights, flanged 6″, nine feet	22
„ and spigot 6″ × 4½′	1*

Well No. 3 (*also Well No. 6*)—

T. piece, socket 6″, flange = 7″ and T. end flanged 4″	1
Straights, flanged 7″ × 9′	22
„ and spigot 7″ × 4½′	1*

Well No. 4 (*also Well No. 5*) -

T. piece, socket 7″, flange 8″ and T. end flanged 4″	1
Bend, flanged and socket 8″ × 0′	1
Straights, flanged 8″ × 9′	23

Add between Well Nos. 6 and 7—

Bend flanged 6″ × 0′	1
Add at Suction Chamber	
Y. piece 10 × 8 × 8	1
Sluice valve 8″	1

Well Fittings—

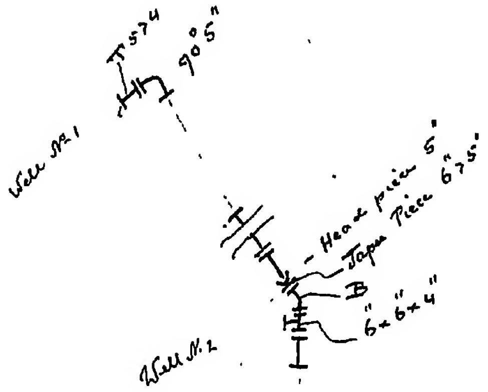
Sluice valves 4″ flanged	8
Bends flanged 90° × 4″	8
Straights flanged 4″ × 9′	16
„ „ 4″ × 7′	8
„ „ 4″ × 4′ (breaking)...	8
„ „ 4″ × 4′ (adjusters)	4
„ „ 4″ × 2′ „	8
Foot-valves 4″	8

* Two 4½′ lengths will be made by cutting 9′ length in two, thus adjusting slight differences in distances between wells.

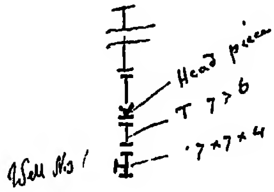
ABSTRACT OF PIPING, Etc.

(1) Straights nine feet flanged—

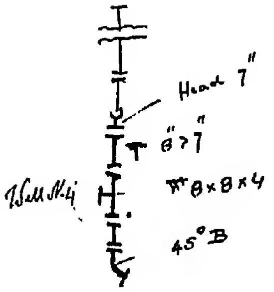
4″ 16 & 4 spare = 20 at 1·473 cwt.	99·46	cwt.
5″ 45 & 2 „ = 47 at 2·112 „	99·26	„
6″ 45 & 2 „ = 47 at 2·520 „	118·44	„
7″ 45 & 2 „ = 47 at 3·426 „	161·02	„
8″ 46 & 2 „ = 48 at 3·862 „	185·38	„
Total ...	593·56	„
Add for variation in weight ...	5% 29·68	„
Total ...	623·24	„



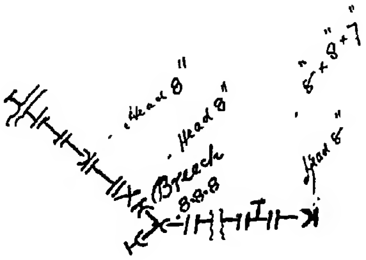
Well No 1
Head piece 5"
Taper Piece 6"> 5"
B
6"x6"x4"
Well No 2



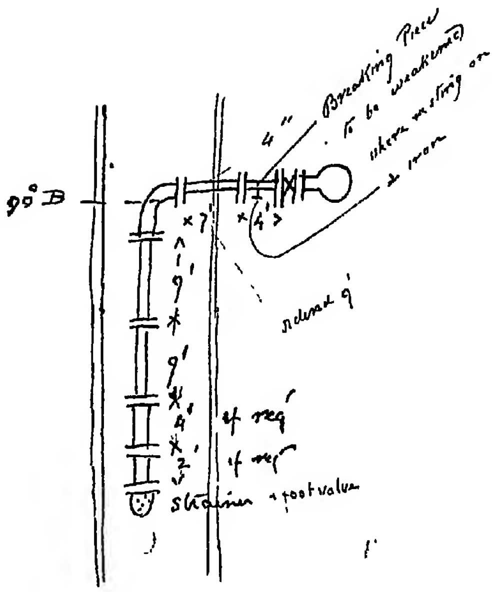
Head piece
T 7>6
7x7x4
Well No 3



Head 7"
T 8">7"
8x8x4
Well No 4
45° B



Head 8"
Head 8"
Breech
8·8·8
8"x8"x7"
Head 8"



90° B
4" Breaking Piece
to be weakened
where no string on
& iron
Strainer & foot valve

(2) Specials—

Straights seven feet flanged 4″—		
8 and 1 spare, 9 at 1·125 cwt.	... ...	10·13 cwt.
Straights four feet long, flanged 4″—		
12 and 2 spare, 14 at 0·7 cwt.	... ...	9·80 "
Straights two feet long, flanged 4″—		
8 ... 8 at 0·4 cwt.	... ...	3·20 "
Bends 4″ flanged 90 –		
8 and 1′ spare, 9 at 0·7 cwt. ...	... ...	6·30 "
Bends 5″ flanged 90—		
2 ... 2 at 1·0 cwt.	... ...	2·0 "
Bends 6″ flanged and socket—		
1 ... 1 at 1·2 cwt.	... ...	1·20 "
Bends 8″ flanged and socket—		
1 of 1 of 2 at 2·0 cwt.	... ...	4·00 "
T. pieces socket 5″, flange 6″, T. end flanged 4″—		
2 ... 2 at 1·4 cwt.	... ...	2·80 "
" socket 6″, flange 7″, T. end flanged 4″—		
2 ... 2 at 1·7 cwt.	... ...	3·40 "
" socket 7″, flange 8″, T. end flanged 4″—		
2 ... 2 at 2·0 cwt	... ...	4·00 "
Y pieces 10 × 8 × 8, 1 at 4·0 cwt ...	... ...	4·00 "
	Total ...	50·83 "
	Add for variation in weights 5%	2·54 "
	Total ...	53·37 "

(3) Sluice Valves flanged –

4″ 8

(4) Sluice Valves flanged—

8″ 2

(5) Foot Valves and Strainers—

4″ 8

(6) Bolts each with nuts and 2 washers complete--

For 4″ piping, etc.
" 20 straights 9′
" 9 " 7′
" 14 " 4′
" 8 " 2′
" 9 bends.
" 6 T. pieces.
" 8 Sluice valves.
" 8 Foot valves.

82 Total joints of 4 bolts ¾″ diameter, 2⅞″ below heads

4 × 82 and 30 spare = 330 @ 0·9 lbs. ... ... 297 lbs.

Brought forward ... 297 lbs.

For 5″ piping.
,, 47 straights.
,, 2 bends.

49 Total joints of 4 bolts ¾″ diameter, 3½″ below heads

4 × 49 and 20 spare = 216 @ 0·93 lbs. ... ... 201 lbs.

For 6″ piping, etc.
,, 47 straights.
,, 1 bend.
,, 1 T. piece.

49 Total joints of 4 bolts 7/8″ diameter, 3¼″ below heads

4 × 49 and 20 spares = 216 @ 1·41 lbs. ... ... 305 lbs.

For 7″ piping, etc., 47 straights.
1 T. piece.
For 8″ piping, etc., 48 straights.
2 bends.
2 T. pieces.
2 valves.

102 joints of 6 bolts.
1″ diameter, 3⅝″ below heads

6 × 102 and 61 spares = 673 No. @ 3·11 lbs. ... 2,086 lbs.

2,889 lbs. = 25·8 cwt.

Lead Wire—

4″ piping, 82 joints.
5″ ,, 49
6″ ,, 49
7″ ,, 48
8″ ,, 54
= 282 @ 3 lbs. .. .. = 846 lbs. = 7·6 cwt.

SUCTION MAIN.

ABSTRACT OF ESTIMATED COST

Serial Sub-head No.	Quantity.	Denomination.	Sub-heads of Works.	Rate.	Per.	Estimated Cost.	European Stores.
				Rs.		Rs.	
1	623·24	cwt.	Flanged Straight Pipes	12	cwt.	7,479	
2	53·37	„	Specials	20	„	1,067	
3	8	No.	Sluice Valves 4" ...	40	each	320	
4	2	„	„ „ 8" ...	90	„	180	
5	8	„	Foot valves and Strainers	50	„	400	
6	25·8	cwt.	Bolts and Nuts ...	25	cwt.	645	
7	7·6	„	Lead	50	„	380	
			Total Estimated Cost of Suction Main ...			10,471	

ESTIMATE OF HEAD WORKS.

DETAILS OF ESTIMATED COST.

Serial No. and Name of Sub-head and details of Work.	Dimensions.				Numbers, Contents or Area.	Total.	Grand Total.
	Number	Length.	Breadth.	Height or Depth.			
LAND.							
(1) Head work ...	1	1,800	800	...	1,440,000	...	...
Quarter	1	250	215	...	53,750	...	...
Road	1	393	30	...	11,790	1,505,540	...
							34·5 acres.
(2) Boundary railing, etc.	2(1,800	+ 800 +	215) +	250	...	...	5,880′
(3) Gates .. .	2	.	. .	...	...	...	2
(4) Wells	8	See	detailed	estimate		...	8
(5) Pipes in suction main, etc.	1	See	detailed	estimate		...	1
(6) Engine-house ...	...	80	40	...	...	...	3,200
(7) Chimney	1	...	...	...	...	...	1
(8) Coal-yard	1	...	...	..	...	...	1
(9) Tunnel	...	1,650	...	...	...	...	1,650
(10) Pumping Plant ..	1	...	...	...	...	...	1
(11) Erection	1	..	...	...	...	...	1

Contrat signé par [illegible] & Cie
pr compléter [illegible]
réparation

{ £ 5,186 = –

[illegible] 77,770 –

HEAD WORKS.

ABSTRACT ESTIMATED COST.

Serial Sub head No.	Quantity	Denomination.	Sub-heads of Works.	Rate.	Per.	Estimated Cost.	Land and European Stores.
				Rs.		Rs.	Rs.
1	34·5	acres.	Land	500	acre.	17,250	17,250
2	5,880	ft.	Boundary railing, etc.	1	ft.	5,880	...
3	2	No.	Gates	50	each	100	...
4	8	No.	Wells see detailed estimate	3,305	each	26,440	...
5	1	Set.	Piping see detailed estimate	...	...	10,471	8,380
6	3,200	s.ft.	Engine-house	3	s. ft.	9,600	...
7	1	No.	Chimney	...	...	1,000	...
8	1	No.	Coal yard	...	...	400	...
9	1,650	l.ft.	Tunnel...	4/4/-	ft	7,013	...
10	1	No.	Pumping plant ...	...	...	75,400	75,400
11	1	No.	Erection of plant ..	...	...	10,000	...
			Total Cost of Head works ...			1,63,554	1,01,030

SUPERINTENDENT'S QUARTERS.

ABSTRACT OF ESTIMATED COST.

Serial Sub-head No.	Quantity.	Denomination.	Sub-heads of Works.	Rate.	Per.	Estimated Cost.	European Stores.
				Rs. A.		Rs.	
1	1,074	c.ft.	Excavation for foundation	5 0	%o	5	
2	631	"	Concrete in foundation	10 0	%	63	
3	403	"	Stone in lime masonry in foundation and plinth	13 0	%	52	
4	412	"	Superstructure stone in lime masonry ...	14 0	%	58	
5	223	"	Stone in mud masonry in foundation and plinth	8 8	%	19	
6	2,461	"	Stone in mud masonry in superstructure ...	10 0	%	246	
7	208	s ft.	Stone slab lintels ...	20 0	%	42	
8	8 3	cwt	Rolled steel beams ...	9 0	cwt.	74	
9	1,543	s.ft.	Terraced roof complete	30 0	%	462	
10	3,100	"	Lime plaster	4 0	%	124	
11	1,303	"	Lime pointing... ...	2 0	%	26	
12	273	"	Teak wood doors and windows complete with chokuts and shutters $1\frac{1}{2}''$ thick ...	1 8	s.ft.	310	
13	933	"	Chunam flooring on 3" concrete	12 0	%	112	
14	1	Job	Earth filling in plinth only ramming and watering is charged...	Lump	Sum	3	
15	4,014	s.ft.	White washing ...	0 4	%	10	
16	1	Job	Cleaning site	Lump	Sum	5	
			Total Cost ...			1,611	

SUPERINTENDENT'S QUARTERS, OUT-HOUSES.

ABSTRACT OF ESTIMATED COST.

Serial Sub-head No.	Quantity.	Denomination.	Sub-heads of Works.	Rate.	Per.	Estimated Cost.	Remarks.
				Rs. A.		Rs.	
1	936	c.ft.	Excavation for foundation	5 0	‰	5	
2	534	,,	Concrete in foundation	10 0	%	53	
3	322	,,	Stone in lime masonry in foundation and plinth	13 0	%	42	
4	176	,,	Stone in mud masonry in foundation and plinth	8 8	%	16	
5	1,047	,,	Stone in lime superstructure	14 0	%	146	
6	1,234	,,	Stone in mud superstructure	10 0	%	123	
7	74	s.ft.	Stone slab lintels ...	20 0	%	15	
8	140	,,	Stone slabs for shelves	16 0	%	22	
9	2 4	cwt.	Rolled steel beams ...	9 0	cwt.	22	
10	954	s.ft.	Terraced roof complete	30 0	%	286	
11	47	,,	Country wood doors and windows complete with chokuts...	1 2	s ft.	53	
12	30	,,	Teak wood doors and windows complete with chokuts ...	1 8	,,	45	
13	2,014	,,	Lime plaster	4 0	%	81	
14	1,128	,,	Lime pointing ...	2 0	%	23	
15	178	,,	Srinager stone flooring on 3″ concrete ...	14 0	%	25	
			Carried over			957	

SUPERINTENDENT'S QUARTERS, OUT-HOUSES—(Concluded).

ABSTRACT OF ESTIMATED COST.

Serial Sub-head No.	Quantity.	Denomination.	Sub-heads of Works	Rate.	Per.	Estimated Cost.	Remarks.
				Rs A.		Rs.	
			Brought forward ...	...	...	957	
16	323	s ft.	Chunam flooring on 3" concrete	12 0	%	39	
17	1	Job	Iron grating for chulas	Lump	Sum	2	
18	1	"	Excavated be filled in plinth, ramming and watering charges only ...	Lump	Sum	2	
19	2,522	s ft.	White washing ...	0 4	%	6	
20	1	Job	Adjusting and cleaning site...	Lump	Sum	5	
				Total	...	1,011	

DRIVERS' QUARTERS.

ABSTRACT OF ESTIMATED COST.

Serial Sub-head No.	Quantity.	Denomination.	Sub-heads of Works.	Rate.	Per.	Estimated Cost.	European Stores.
				Rs. A.		Rs.	
1	2,018	c.ft.	Excavation for foundation	5 0	°/°°	11	
2	1,265	"	Concrete in foundation.	10 0	%	127	
3	800	"	Stone in lime masonry in foundation and plinth.	13 0	%	104	
4	390	"	Stone in mud masonry in foundation and plinth	8 8	%	33	
5	577	"	Stone in lime masonry in superstructure ...	14 0	%	81	
6	2,503	"	Stone in mud masonry in superstructure ...	10 0	%	250	
7	147	s.ft.	Stone slab lintels, 4" to 6"	20 0	%	29	
8	352	"	Stone slabs for shelves.	16 0	%	56	
9	9·8	cwt.	Rolled steel beams ...	9 0	cwt.	88	
10	1,691	s.ft.	Terraced roof, complete.	30 0	%	507	
11	4,759	"	Lime plaster	4 0	%	190	
12	262	"	Country wood doors and windows, complete ...	1 2	s.ft.	393	
13	2,326	"	Lime pointing ...	2 0	%	47	
14	1,046	"	Chunam flooring on 3" concrete	12 0	%	126	
15	1	Job	Earth ramming and watering in plinth (excavated earth to be used)	Lump	sum	5	
16	5,261	s.ft.	White washing ...	0 4	%	13	
			Carried over ...			2,060	

DRIVERS' QUARTERS—(*Concluded*).

ABSTRACT OF ESTIMATED COST.

Serial Sub-head No.	Quantity.	Denomination.	Sub-heads of Works.	Rate.	Per.	Estimated Cost.	European Stores.
				Rs. A.		Rs.	
			Brought forward ...	...	...	2,060	
17	4	No.	Iron latrine, complete	52 0	each	208	
18	5	c.ft.	Ghugra cut stone for the ends of drain ...	2 0	c.ft.	10	
19	2	No.	Iron receptacles ...	5 0	each	10	
20	1	Job	Cleaning site, etc. ...	Lump	sum	5	
				Total	...	2,293	

ASSISTANT DRIVERS' QUARTERS.

ABSTRACT OF ESTIMATED COST.

Serial Sub-head No.	Quantity.	Denomination.	Sub-heads of Works.	Rate.	Per.	Estimated Cost.	European Stores.
				Rs. A.		Rs.	
1	2,849	c.ft.	Excavation for foundation	5 0	°/..	14	
2	1,608	„	Concrete in foundation.	10 0	%	161	
3	2,683	„	Stone in lime masonry in foundation and plinth.	13 0	%	349	
4	374	„	Stone in mud masonry in foundation and plinth.	8 8	%	328	
5	882	„	Stone in lime masonry in superstructure ...	14 0	%	141	
6	4,692	„	Stone in mud masonry in superstructure ...	10 0	%	469	
7	196	„	Stone slab lintels ...	20 0	%	39	
8	645	„	Stone slabs for shelves.	16 0	%	74	
9	8·6	cwt.	Rolled steel beams ...	9 0	cwt.	77	
10	2,220	s.ft.	Terraced roof, complete.	30 0	%	666	
11	312	„	Country wood doors and windows, complete with frames... ...	1 2	s ft.	390	
12	5,214	„	Lime plaster	4 0	%	209	
13	4,549	„	Lime pointing... ...	2 0	%	91	
14	5,655	„	White washing ...	0 4	%	14	
15	1,821	„	Chunam flooring on 3″ concrete	12 0	%	219	
16	1	Job	Filling in plinth, ramming and watering is charged only ...	Lump	sum	10	
17	4	No.	Receptacles	5 0	each	20	
18	1	Job	Cleaning site	Lump	sum	10	
19	1	„	Two seated iron latrine.	52 0	each	104	
				Total ...		3,185	

RISING MAIN.

DETAILS.

(1) Cast Iron Pipes nine foot Straights Spigot and Socket—

From 0′ to 9,000′ = 9,000′

1,000 pipes $\frac{5}{8}$″ thick + 2 % for breakages	cwt.
1,020 pipes @ 5·711 cwt.	5,825
From 9,000′ to 31,115 = 22,115 and 39,115′ to 56,715 = 17,600 } 39,715′	
4,413 pipes $\frac{9}{16}$″ thick + 2 % for breakages	
4,501 pipes @ 5,160 cwt.	23,225
	29,050
3 % irregularities in casting	872
	29,922

(2) Carriage and laying of 9″ pipes—

31,115′ to 39,115′ ... ... 8,000 ft.

(3) Bends and other forms—

10″ At Pumping Station Flanged piece	1 at ·75 ...	·75
Do. 90° Bends S. and S.	2 at 2·5 ...	5·00
At Reservoir Tee S. and S. 10 × 10 × 10	2 at 3·0 ...	6·00
At Reservoir Head and Tail pieces	2 at 3·0 ...	6·00
At City Reservoir Tee S. and S. 10 × 10 × 10 ...	1 at 3·0 ...	3·00
Do. Head and Tail pieces	2 at 3·0 ...	6·00
At 31,115′ and 39,115′ Tapers 10 to 9	2 at 2·5 ...	5·00

10″ S. and S. pieces with flanged Tee—

Position.	For Air Valves 10 × 10 × 3.	For Sluice Valves 10 × 10 × 8.	
400′	...	1	
9,850′	1	...	
10,350′	...	1	
11,600′	1	...	
11,750′	...	1	
11,800′	1	...	
12,000′	...	1	
12,500′	1	...	
12,685′	...	1	
12,820′	1	...	
13,600′	...	1	
19,000′	1	...	
19,167′	...	1	
28,750′	...	1	
Carried over ...	6	8	31·75

The Indent No. 5 is for 5,000 pipes only weighing 26,240 cwt

a saving of 3,682 cwt @ 9/- £ 33,138/=

The requirements are even less than this being 4,468 pipes

The rates for pipes id go up to 10¼ from 9

Position.	For Air Valves 10 × 10 × 3.	For Sluice Valves 10 × 10 × 8.		
Brought forward ...	6	8		31·75
30,390′ ...	1	...		
41,215′ ...	...	1		
44,415′ ...	1	...		
47,415′ ...	...	1		
48,915′ ...	1	...		
53,615′ ...	...	1		
	9	11		
Add spares ...	1	1		
			cwt.	cwt.
	10	...	@ 3·0	30·00
		12	@ 3·3	39·60
				101·35

10″ S. and S. Quarter Bends—

10,000′ ...	1		
10,200′ ...	2		
10,400′ ...	2		
15,400′ ...	1		
17,000′ ...	1		
17,200′ ...	1		
18,000′ ...	1		
18.200′ ...	2		
18,800′ ...	3		
19,100′ ...	1		
20,000′ ...	1		
20,400′ ...	2		
22,500′ ...	1		
Reservoir ...	2		
28,500′ ...	1		
51,900′ ...	1		
56,015′ ...	2		
City Reservoir ...	4		
	29		
Spare ...	1		
		30 @ 2·5 cwt.	75·00 cwt.

9″ S. and S. pieces with flanged Tees—

	9″ × 9″ × 3″ For Air Valves.	9″ × 9″ × 6″ For Scours.		
33,500′ ...	...	1		
34,200′ ...	1	...		
39,000′ ...	...	1		
	1	2	= 3 @ 2·5	7·50
		Carried over ...		183·85

		Brought forward ...	183·85 cwt.
9″ Quarter Bends S. and S.			
37,100... ... 1			
39,000... ... 1			
	2 at 2·0	... ...	4·00
9″ Head and Tail piece at Foysager	1 at 2·5	... ...	2·50
12″ T. Piece S. and S. 12 × 12 × 9 at Foysager	1 at 5·0	... ...	5·00
Collars, etc, 12″	2 at 1·2	... ...	2·40
10″	20 at ·8	... ...	16·00
9″	10 at ·7	... ...	7·00
			220·75 cwt.

(4) Sluice Valves—

(4)	10″ at Reservoir	1		
	at Foysager	1	... ...	2
(5)	9″ at Foysager	1	... ...	1
(6)	8″ on 10″ pipe scours ...	11	... ...	11
(7)	6″ on 9″ pipe scours ...	2	... ...	2

(8) Air Valves—

10″ pipe	9		
9″	1	... ...	10

(9) Rock Cutting—

For 12,000 to 22,450
10,450 × 3′ × 3′ ... ... 94,050 c.ft.

(10) Bolts and Nuts—

Item 4 ...	... 2	at 13·00 lbs.	... ...	26·00 lbs.
5 ...	... 1	,, 12·75	... ...	12·75
6 ...	... 11	,, 12·5	... ...	137·50
7 ...	... 2	,, 5·75	... ...	11·50
8 ...	... 10	,, 2·25	... ...	22 50
				210·25 ÷ 112 = 1·9 cwt.

RISING MAIN.

ABSTRACT OF ESTIMATED COST.

Serial Sub-head No.	Quantity.	Denomination.	Sub-heads of Works.	Rate.	Per	Estimated Cost.	European Stores.
				Rs. A.		Rs.	Rs.
1	29,922	cwt.	Cast iron, straight pipes	9 0	cwt.	2,69,298	2,15,438
2	8.000	l.ft.	Laying, etc., 9″ pipes...	0 12	l.ft.	6,000	...
3	221	cwt.	Bends and other form...	15 0	cwt.	3,315	2,652
4	2	No.	Sluice valves 10″ ...	120 0	each	240	192
5	1	„	„ 9″ ...	100 0	„	100	80
6	11	„	„ 8″ ...	80 0	„	880	704
7	2	„	„ 6″ ...	60 0	„	120	96
8	10	„	Air valves flanged ...	30 0	„	330	264
9	94,050	%	Rock cutting	3 0	% c.ft.	2,822	...
10	1·9	cwt.	Bolts and nuts ...	25 0	cwt.	48	39
				Total ...		2,83,153	2,19,465

CIRCULAR RESERVOIR.

ABSTRACT OF ESTIMATED COST.

Serial Sub-head No.	Quantity.	Denomination.	Sub-heads of Works.	Rates.	Per	Estimated Cost.	European Stores.
				Rs. A.		Rs.	
1	18,836	c.ft.	Excavation in earth and moorum	10 0	°/..	188	
2	12,031	„	Excavation in earth and moorum and soft rock...	25 0	„	301	
3	12,031	„	Excavation in earth and moorum in hard rock.	40 0	„	481	
4	15,744	„	Concrete filling ...	14 0	%	2,204	
5	6,977	„	Coarsed rubble stone in lime masonry ...	25 0	%	1,744	
6	631	s.ft	Stone slab coping ...	30 0	%	189	
7	2,330	„	Lime plaster with cement plaster ½" thick and fine skin inside...	8 0	%	186	
8	1,313	„	Lime pointing outside	2 0	%	26	
9	454	lbs.	Iron work	0 2½	lbs.	71	
10	144	s.ft.	Wire netting mesh ...	1 0	s.ft.	144	
11	1	Job	Cleaning site and filling earth, ramming and watering outside the Reservoir	Lump	sum	100	
			Total of the above ...			5,634	

	~~Rs~~
Actual cost (?)	6,186
Contents	1,66,670 gallons
or say	28 g/R

Approx: cost

England	2, 45, 500	
Land	33, 250	
Carriage	37, 000	3, 15, 700
× India	1, 85, 000	
	5, 00, 750	
24½% on ×	45, 325	
	5, 46, 000	
deduct sales	15, 000	
	5, 31, 000	
estimate	5, 19, 462	
Excess	11, 500	

4.83, 461
24, 173
5, 07, 634

5.19.462
25, 973
5, 45, 435

5%

SAGARMATI WATER WORKS 1913-1914.

ABSTRACT OF ESTIMATE.

Serial Sub-head No.	Works.	English Works and Land.	Indian Work.	Total.
		Rs.	Rs.	Rs.
1	HEAD WORKS	1,01,030	62,524	1,63,554
	QUARTERS.			
2	(a) Superintendent	...	1,611	...
3	(b) Out-houses	...	1,011	...
4	(c) Drivers'	...	2,293	...
5	(d) Assistant Drivers'	...	3,185	8,100
6	RISING MAIN	2,19,463	63,688	2,83,151
7	RESERVOIR	...	5,634	5,634
	Total ...	3,20,493	1,39,946	4,60,439
8	5% Contingencies	16,025	6,997	23,022
9	Establishment @ 23%	...	33,797	33,797
10	Tools and Plant @ 1½%...	...	2,204	2,204
	GRAND TOTAL ...	3,36,518	1,82,944	5,19,462

H. C. SANDERS,
SUPERINTENDING ENGINEER,
Secretary to the A. G.-G. in the P. W. D., Rajputana.

AJMER, *3rd February 1913.*